Opportunities for Avoided Deforestation with Sustainable Benefits

An interim report of the
ASB partnership for the Tropical Forest Margins

November 2007

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ASB
PARTNERSHIP FOR THE TROPICAL FOREST MARGINS

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Brent Swallow[1], Meine van Noordwijk[1], Sonya Dewi[1], Daniel Murdiyarso[2], Douglas White[3], Jim Gockowski[4], Glenn Hyman[3], Suseno Budidarsono[1], Valentina Robiglio[4], Vanessa Meadu[1], Andree Ekadinata[1], Fahmuddin Agus[5], Kurniatun Hairiah[6], Peter Mbile[1], Denis J. Sonwa[4], Stephan Weise[4]

1. World Agroforestry Centre (ICRAF), Bogor/Nairobi/Yaoundé, Indonesia/Kenya/Cameroon
2. Centre for International Forestry Research (CIFOR), Bogor, Indonesia
3. International Centre for Tropical Agriculture (CIAT), Cali, Colombia
4. International Institute for Tropical Agriculture (IITA), Yaoundé / Accra, Cameroon / Ghana
5. Indonesian Soil Research Institute, Bogor, Indonesia
6. Brawijaya University, Malang, Indonesia

An interim report of the Alternatives to Slash and Burn Partnership for the Tropical Forest Margins.

November 2007

Contact author: Brent Swallow (b.swallow@cgiar.org)

Correct citation:
Swallow, B, M. van Noordwijk, S. Dewi, D. Murdiyarso, D. White, J. Gockowski, G. Hyman, S. Budidarsono, V. Robiglio, V. Meadu, A. Ekadinata, F. Agus, K. Hairiah, P.N. Mbile, D.J. Sonwa, S. Weise. 2007. *Opportunities for Avoided Deforestation with Sustainable Benefits. An Interim Report by the ASB Partnership for the Tropical Forest Margins.* ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya.

Acknowledgements:
The authors are grateful to the following donors organizations for helping to finance the preparation and publication of this report: the European Union support for policy research at the World Agroforestry Centre, the World Bank support to Systemwide and Ecoregional Programmes, and the Government of Canada and International Institute for Sustainable Development for support to Vanessa Meadu. We also gratefully acknowledge the long list of previous donors and contributors to ASB that helped build up the methods and data that laid the foundation for this analysis,

This report was developed with personal contributions from Lou Verchot, Joyce Kasyoki, Peter Akong Minang, Laura Ivers, Michael Hailu, and Reagan Sirengo.

Thanks also to the partner institutions which supported this work: Brawijaya University, Malang, Indonesia; Centre for International Forestry Research (CIFOR), Bogor, Indonesia; Indonesian Soil Research Institute, Bogor, Indonesia; International Centre for Tropical Agriculture (CIAT), Cali, Colombia; International Institute for Tropical Agriculture (IITA), Yaoundé / Accra, Cameroon / Ghana; World Agroforestry Centre (ICRAF) Bogor/Nairobi/Yaoundé, Indonesia/Kenya/Cameroon.

Cover illustration and design: Reagan Sirengo (rsirengo@gmail.com)

For further information contact:

Global Coordinator, ASB Partnership for the Tropical Forest Margins,
World Agroforestry Centre
P.O. Box 30677
Nairobi, Kenya

Tel: +254 20 722 4139/722 4000 or +1 650 833 6645
Fax: +254 20 722 4001 or +1 650 833 6646
Website: http://www.asb.cgiar.org
E-mail: asb@cgiar.org

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Acronyms and Abbreviations

AFOLU	Agriculture, Forestry and Other Land Uses
ASB	Alternatives to Slash-and-Burn Partnership for the Tropical Forest Margins
BAU	Business as Usual
C	Carbon
CDM	Clean Development Mechanism of the Kyoto Protocol
CO2	Carbon dioxide
CO2eq	Carbon dioxide equivalent
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)
CIFOR	Center for International Forestry Research
ETS	Emission Trading Scheme
EU	European Union
EUR	euro, the official currency of the European Union
GHG	Greenhouse gas
Ha	hectare
ICRAF	International Centre for Research in Agroforestry (World Agroforestry Centre)
INIA	Instituto Nacional de Investigación Agraria
RED	Reduced Emissions from Deforestation
REDD	Reduced Emissions from Deforestation and forest Degradation
TSBF	Tropical Soil Biology and Fertility Institute
UNFCCC	United Nations Framework Convention on Climate Change
UNU	United Nations University

Figures, Tables and Text Boxes

Opportunities for Avoided Deforestation with Sustainable Benefits

Executive Summary

Trees and forests play important roles in global climate change mitigation. On the one hand, trees growing in forests and on farms are one of the world's greatest sinks of carbon. Afforestation in Europe now offsets significant amounts of global emissions and there are many unexploited opportunities for afforestation and reforestation in the developing world. On the other hand, tropical deforestation is one of the largest sources of greenhouse gas emissions. The Intergovernmental Panel on Climate Change estimate that in 2004, the forest sector was responsible for 17.4% of global greenhouse gas emissions.

Global-level studies of the economics of climate change mitigation indicate that afforestation and avoided deforestation are among the most attractive investments for reducing net greenhouse gas emissions (total emissions less total sequestration). The ASB Partnership for the Tropical Forest Margins has conducted biophysical, socioeconomic and institutional research on the tradeoffs associated with alternative land uses in the humid tropics. Building on previous research at the ASB benchmark sites, this paper presents spatially-explicit analyses of the tradeoffs between carbon and economic returns in three sites in Indonesia, and one site in each of Peru and Cameroon. Located in the humid forest zones of Southeast Asia, the Amazon basin, and Central Africa, these sites represent a range of the conditions that shape tree and forest management across the humid tropics. Indonesia is particularly distinguished by having the world's highest levels of land-based emissions of greenhouse gases and largest CO_2 emissions from conversion of peat lands.

Results presented in this report indicate similarities and differences across the sites. The patterns of land use transition over the last 10-20 years vary considerably, with some sites experiencing general trends of carbon-emitting land use changes, while others experiencing a balance of carbon-emitting and carbon-sequestering land use changes. In general, however, the carbon losses due to carbon-emitting forest conversion vastly exceed the carbon gains due to carbon-sequestering land use changes. This is exemplified by the Indonesian province of East Kalimantan. Although it has experienced more sequestering land use changes than emitting land use changes, the province has on net lost huge amounts of carbon overall since 1990. . This is because the carbon-emitting land use changes have resulted in average losses of 230 tonnes per hectare per in the year that they occur, while shifts from lower to higher carbon-sequestering land uses have resulted in just 4 tonnes of sequestration per hectare per year.

Further results from across the 3 provinces of Indonesia indicate that there is, even without specific support programs, substantial activity to restore carbon to landscapes that have been previously degraded. In East Kalimantan, the bulk of the carbon-sequestering land use changes are natural regrowth from cleared land, while in Jambi the transition to carbon-sequestering land uses mostly represent transitions from cropland to rubber agroforestry systems. Win-win solutions are possible: transitions from cropland to rubber agroforestry in Jambi and from coffee to complex damar agroforestry in Lampung increase returns to farmers and time-averaged carbon stocks. In Cameroon, shifts from crop-fallow systems agriculture into shaded cocoa systems can also be such a win-win solution.

The analysis of the economic returns associated with the land use transitions (measured in terms of discounted net present value) shows that there is clear economic rationale for almost all of the land use transitions occurring in the 5 sites. That is, almost every land use transition has been economically rational from the perspective of private land users responding to: market incentives to harvest and sell timber; market opportunities for new cash crops; the lack of incentives they have to maintain the value of standing carbon, and high interest rates in local financial markets.

Expressed in terms of tonnes of emissions of carbon dioxide equivalents (CO_2eq), however, the economic gains associated with deforestation are very low. In the three provinces of Indonesia included in the study, between 6 and 20% of the area where emissions increased have generated returns less than 1$ per tonne of CO_2eq and between 64 and 92% of the emission generating changes have resulted in returns less than 5$ per tonne of CO_2eq. In the benchmark site in Ucayali Province in Peru, over 90% of emissions from

land use change have generated returns less than 5$ per tonne of CO_2eq. If carbon stock of standing forests were valued and sellable during 20 years, a large percentage of greenhouse emissions from deforestation in the Indonesia and Peru sites might have been avoided. Current market and incentive conditions in the humid tropics continue to inadequately provide incentives for cost-effective reduction of CO_2 emissions.

The global analysis also reveals heterogeneity in carbon stocks in humid tropical forests. Results from the Indonesian province of Jambi show that peat forests, as well as other peat lands, should be given special attention in negotiations and programmes for reduced emissions from deforestation and forest degradation. The customary slash-and-burn system known as "sonor" is particularly damaging to the atmosphere, releasing large amounts of carbon from the rich peat soils, while providing very little return in terms of income to the local farming populations. The return per tonne of CO_2 emitted is as low as US$0.10-0.20 in those landscapes.

Policy makers concerned about carbon emissions can and should harvest some low hanging fruits by devising early and effective mechanisms for compensating land users for the carbon storage value of forests and trees. Policy makers should pay greater attention to below-ground carbon, particularly the need to conserve the peat lands of Indonesia that store large amounts of carbon. Investments in these high carbon payoff areas can clearly be a good deal for investors and for the planet. To be effective, sustainable and fair, the deals will also have to make good sense for the tens of millions of farmers and other rural residents whose actions together drive land use change in the tropical forest margins.

Key Messages:
This report contains the following key messages for international, national and local efforts to mitigate climate change.

(1) There are cost-effective opportunities for large reductions in CO_2 emissions from avoided deforestation in the humid tropics, provided that appropriate institutions and incentive systems are created. Every year of delayed action means a year more of large emissions that could have been avoided at relatively little cost to the world economy. Governments and other stakeholders should take positive pragmatic steps at the same time as they negotiate how to incorporate REDD into new long-term agreements.

(2) Urgent attention should be given to reducing emissions from the peatlands of Southeast Asia. This includes stopping conversion of peat forests and modifying farming practices on previously-converted peatlands, mostly by reducing the depth of drainage. Current negotiations about Reduced Emissions from Deforestation and Forest Degradation (REDD) should cover not just forested peat lands, but all peat lands.

(3) In the absence of incentives for landowners to maintain forest resources, market conditions generally favour conversion of forests over conservation. However, accounting for lost carbon values, this study shows huge economic losses associated with land use change in all of the study sites. Accounting for the value of other environmental services (such as biodiversity conservation), other climate benefits of forests, and the economic loss due to climate change, would undoubtedly show even greater losses. To be effective in the long-term, REDD mechanisms must provide land users with financial incentives that outweigh the returns from conversion to other land uses. Our study shows this could be done cost-effectively. In the absence of carbon markets for avoided deforestation, emission reduction in Europe may cost 100 times greater per unit than the financial value that is generated by emissions in the tropical forest margins

(4) We have observed a considerable amount of carbon-sequestering land use changes that have also increased net returns to farmers. This implies that incentives for re/afforestation may foster further land use changes that increase income and sequester carbon. This study shows that establishing multi-strata agroforestry systems on degraded lands– where farmers integrate a range of trees into their farming systems -- is such an opportunity. Elsewhere, some community forestry systems have been shown to represent a similar opportunity.

(5) Besides providing appropriate monetary or in-kind compensation for avoided land-use change, REDD schemes should address both the need for alternative sources of livelihood for the affected populations, as well as the need to produce alternative sources of wood products for local uses. Again, both agroforestry systems and community forestry can produce such win-win solutions.

(6) Given the importance of international market conditions in shaping land use transitions in the humid tropics, it is highly likely that patterns of consumption, trade and environmental regulation in the countries that consume the products of tropical forest landscapes will spill over into incentives for land use change in developing countries. International organizations, national governments and industry groups should be aware of these positive spillovers and take action to reduce negative impacts. Green premiums for rubber, cocoa and coffee produced from carbon-rich systems need further encouragement and support.

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1. Introduction

> *The loss of natural forests around the world contributes more to global emissions each year than the transport sector. Curbing deforestation is a highly cost-effective way to reduce emissions; large-scale international pilot programmes to explore the best ways to do this should get underway very quickly* (Press Release on Publication of the Stern Review on the Economics of Climate Change by Her Majesty's Treasury, 30 October 2006 http://www.hm-treasury.gov.uk/newsroom_and_speeches/press/2006/press_stern_06.cfm

1.1 The Challenge

The Intergovernmental Panel on Climate Change (IPCC) produces the most authoritative estimates of the contribution of various industries and countries to greenhouse gas emissions. According to the IPCC Fourth Assessment Report of 2007, the forestry sector is currently responsible for 17.4% of global greenhouse gas emissions (Nabuurs et al., 2007). With evidence mounting on the severity of global warming and the inadequacy of the current response, a new consensus is emerging that "Business as Usual" (BAU) scenarios of accelerating increases in emissions and rising atmospheric CO_2 cannot be allowed to become the reality of the next generation. The Stern Review of the Economics of Climate Change (2007) is one of many reports that have recently argued that avoiding deforestation in the tropics should given high priority in future mitigation strategies.

The scientific community has long known about the importance of deforestation as a source of greenhouse gas emissions, although international climate change policy has afforded it less attention than other mitigation options. Avoided deforestation was deliberately excluded from the Clean Development Mechanism of the Kyoto Protocol (CDM). Afforestation and reforestation activities have been allowed under the CDM, but restricted to be less than 5% of Certified Emission Reductions over the 5 years of the first commitment period. The first round of the EU Emission Trading Scheme (ETS) deliberately excluded all forestry and land use projects (also called AFOLU for agriculture, forestry and other land uses), thus excluding both avoided deforestation and reforestation. At the time that this report was prepared, of the 1059 registered CDM projects there was only one approved re/afforestation project[1] in the project portfolio.

Interest in avoided deforestation has been heating up since the 11th Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in 2005 resolved that there should be a 2-year period of discussion about Reduced Emissions from Deforestation (RED) or, as it is mostly known at present, Reduced Emissions from Deforestation and Forest Degradation (REDD). REDD was one of the most heavily debated topics at the meeting of the Subsidiary Bodies to the UNFCCC in Bonn in May 2007.

Compared to other approaches to mitigation of greenhouse gas emissions, REDD is undoubtedly complex. It cannot be done small-scale, as the pressure on forest might simply be shifted ('leakage'). It has to be acknowledged that many forces drive deforestation and forest degradation: forces which vary in form and intensity from place to place across the developing world (Kanninen et al., 2007). Geist and Lambin (2002) reviewed 152 cases of deforestation in Africa, Asia and Latin America and developed a widely-used framework for analyzing and classifying the causes of deforestation. Their model identifies 5 clusters of driving forces. The three clusters of proximate causes are infrastructure extension, agricultural expansion and wood extraction. These proximate causes are influenced by underlying factors (demographic factors, economic factors, technological factors, policy and cultural factors) and a group of other factors (predisposing environmental factors, biophysical drivers, and social trigger events). Another group of studies describe more complex, non-linear, "forest transitions". It is hypothesized that there is an inverted U (or Kuznets) relationship in which deforestation accompanies population expansion and economic development for some period, then levels out before a period of slow and steady afforestation or

[1] Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin http://cdm.unfccc.int/Projects/index.html

at least increase in tree density in the landscape that might not reach the threshold of being called a 'forest'. Rudel et al (2005) propose two main scenarios underlying this transition. One scenario is that growth in the industrial and service sectors draws populations away from agricultural and forest areas, relieving pressures and allowing those areas to regrow naturally. Another plausible scenario is that societies accept high levels of deforestation during certain phases of population expansion and economic development, then progressively place greater value on standing forests as both forest lands and the ecosystem services and forest products that they generate become scarcer and more highly valued.

Partly due to minimal participation at the national level, and none at the community level, most studies of the economics of CO_2 abatement through reduced deforestation have had a top-down orientation, considering avoided deforestation as a kind of technical fix on par, for example, with energy efficiency in the transport sector. Yet there are fundamental differences. Deforestation in the tropics is the result of the complex interplay of hundreds of millions of indigenous and migrant farmers, local and multi-national firms, and non-governmental organizations who tend to exhibit competing interests. The most vulnerable of these groups are members of indigenous, minority and often marginalized ethnic groups living in remote areas of high biodiversity value, yet with very poor physical, economic and human capital endowments. The most numerous are smallholder farmers, and perhaps the most influential are private firms and local elites who seek to exploit forest resources for private and commercial gain. The areas experiencing most active deforestation are located at the increasingly non-contiguous forest – agriculture frontiers, usually far from political and economic power centers and increasingly, less well defined and spatially ubiquitous. Sunderlin, Dewi and Puntodewo (2007) have recently compiled cross-country evidence on the nature of the poverty – forest relationship. Measuring poverty in terms of income, the tropical forest margins are generally associated with high percentages of poverty, although often low densities of human population. Large reductions in deforestation will necessarily entail changes in the land use choices of tens to hundreds of millions of the world's poorest people.

The small number of studies that have examined the economics of avoided deforestation suggest that substantial reductions in emissions from deforestation and forest degradation may be either relatively expensive, or very inexpensive, compared to other mitigation options. Research conducted by Grieg-Gran (2006) for the Stern Commission suggests that the opportunity costs of forest protection in the 8 countries that are responsible for 70% of emissions would initially be around $5 billion / year, rising over time. A recent paper by Obersteiner et al. (2006) suggests that a 50% reduction of carbon emissions over the next 20 years could require as little as $US0.16 billion in 2006 rising to $US2.9 billion in 2025. However, this low cost assumes that carbon payments would just offset the foregone income from deforestation, a very unlikely situation, as transaction costs will have to be accounted for as well as some benefits for other actors in the value chain. More likely, Obersteiner et al (2006) propose, is that there is insufficient data available to investors on the actual opportunity costs of avoided deforestation and that programs would pay more to ensure compliance over the longer term. A study of greenhouse gas abatement conducted by the Vattenfall Energy Company proposes that there are few opportunities to reduce emissions from deforestation for less than EUR10 / tonne CO_2eq. They assumed that reducing emissions from deforestation in Asia would cost an average of EUR35 / tonne CO2eq (Vattenfall AB, 2007). The total costs of 50% reductions in CO_2 emissions at those costs might be similar to the $33 billion / year estimated by Obersteiner et al.

Discussions about the design of REDD mechanisms also suggest complexity. Important technical issues include the challenges of measuring carbon stocks and flows in mixed land-use mosaics. Important institutional issues include national or provincial sovereignty over natural resources, balancing the need to reward good forest stewardship and forestall poor stewardship, state / group / individual property rights to environmental services, and the rights of minority and vulnerable social groups. There also are program design issues such as appropriate geographic scope, standards of accounting and liability, management of resources, unintended side effects on markets or other environmental services, and proof of additionality beyond business as usual. During 2007, the Government of Indonesia and a number of international organizations and donors have engaged in intense discussions of these and similar issues. Options for getting around them have been proposed and debated. Similar discussions and studies need to be held in countries across the tropics. While all such issues are important and will need to be addressed, the primary question addressed by this report is whether or not avoiding emissions could be cost effective compared to other options to reduce emissions. If not, further discussions on institutional mechanisms are not needed; if yes, further exploration is warranted.

Box 1.1 Increased Emissions from Biofuels – a Burning Debate

The Kyoto protocol separated the ‘energy’ from the ‘land based’ emissions, and only imposed accountability for emissions on Annex-I countries. Within these rules it appeared economically efficient to substitute fossil fuel with ‘biofuel’. If emissions from the production of these biofuels were unaccounted for, they remained outside the accounts of Annex I countries. The data on these emissions, points to significant contradictions in the logic of biofuel substitution. Although globally, energy and land use are interlinked, there is currently no accountability for land-based emissions outside of the Annex-I domain.

The push for approaches for mitigating climate change has led to massive interest in biofuels. Non-carbon fossil fuels have gained support from private interests, governments, and NGOs in both industrialized and developing economies. The debate about biofuels boils down to questions of land use: what lands are being converted for biofuel feedstock plantations, and what are the consequences?

In many tropical areas, carbon rich landscapes are being converted for biofuels, with harmful consequences for climate change, ecosystems and people. Should demand for biofuels increase, a massive scaling up of feedstock production would be necessary. Reghelato and Spracklen (2007), argue “such an approach would require very large areas of land in order to make a significant contribution to mitigation of fossil fuel emissions and would, directly or indirectly, put further pressure on natural forests and grasslands”.

In Indonesia and Malaysia, the two highest world palm oil producers, ancient peat forests are being replaced with oil palm plantations. ancient peat forests are being replaced with oil palm plantations. The process of conversion has led to increased emissions. It is estimated that production of one tonne of palm oil results in an average emission of 20 tonnes of CO2 from peat decomposition alone – not taking into account the emissions from fire and other CO2 emissions during the production cycle (Wetlands International 2006)[2] A net increase in GHG emissions is a perverse and contrary result.

Using data generated by ASB and others, Reghelato and Spracklen (2007) conducted a study on cumulative avoided emissions per hectares over 30 years for a range of biofuels. They found that forestation and avoided deforestation “would sequester two to nine times more carbon over a 30-year period than the emissions avoided by the use of the biofuel” (p. 902). To effectively achieve emissions reductions, they advise policymakers to focus on increased efficiency of energy use, conservation of existing forested areas, and restoration of forest in degraded areas.

Beyond climate change, the biofuels debate has strong implications for a broad range of issues that impact people and the environment. Scaling up feedstock production may force competition between food crops and fuel crops, with potential implications for agriculture prices, food security, poverty and nutrition. Biofuels may also promote monocultures, impacting biodiversity. Other risks include increased water demand, increased use of fossil-fuel-based fertilizer, and the degradation of marginal lands. Large-scale production may exclude smallholder farmers, with potential negative impacts on livelihood and rural economic development.

1.2 The ASB Partnership and previous results on carbon – livelihood tradeoffs

The Alternatives to Slash and Burn Partnership (ASB) was established in 1992 and became fully functional in 1994. The original objective was to investigate the local and global causes and consequences of deforestation by small-scale farmers and to identify land use systems that would enhance local livelihoods and the environment, together with the policies and other changes needed to support those land use systems (Sanchez et al., 2005). ASB has maintained an emphasis on these local versus global tradeoffs and relationships, while the program adjusted its course to account for past research results (Tomich et al., 2007). The goal of ASB is now to “*raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services.”* ASB has 80 partner institutions. It has an ecoregional focus on the forest-agriculture margin in the humid tropics, with benchmark sites in the western Amazon basin of Brazil and Peru, the Congo Basin forest in Cameroon, southern Philippines, northern Thailand, and the island of Sumatra in Indonesia.

ASB is best known for its systematic approach to cross-site research and its use of the ASB matrix for cross-site comparisons and analysis of tradeoffs. The concept of meta-land use systems – land uses that occur in some variant in all or most of the sites – has proven to be very important for cross-site comparisons. In each site, important land uses are identified and exclusively categorized into one of the mega land uses. Criteria and indicators for systematic comparison of land uses have been chosen to represent global environmental concerns (carbon sequestration, biodiversity), agronomic sustainability, smallholders' socioeconomic concerns (potential profitability, employment) and policy and institutional issues (production incentives) (Sanchez et al., 2005).

What is particularly relevant to the current study is the ASB work on carbon stocks and tradeoffs between carbon sequestration and potential financial profitability. Four types of above-ground carbon stocks (live trees, understory, dead vegetation, litter layer) and below ground carbon stocks (roots and soil to 20 centimetres of depth) have been measured in sample points along chronosequences of change for each land use type. The measurement protocol was summarized in Palm et al. (2005) and presented in detail in Woomer et al. (2000) and Hairiah et al. (2001). The carbon loss or sequestration potential of a land use system is determined not by the maximum carbon stock of the system or the stocks at any particular point in time, but rather by the average carbon in that land use during a full rotation period. Linear carbon accumulation functions are assumed and allometric equations for tropical moist forest trees used to convert tree diameter to tree biomass. The biomass of vegetation, roots and litter are converted to carbon by multiplying by a factor of 0.45 (Palm et al., 2005).

Box 1.2 Time-averaged carbon stocks

Carbon is both lost and gained from any ecosystem every day, mostly by photosynthesis and respiration. Just as with a bank account, there are many ways of quantifying the performance of the system. Keeping track of all transactions may be complex, but monitoring the bottom-line is simple. Annual increments in the total stock are a useful indicator, but they respond not only to long-term trends but also to specific events during the year, as part of the interannual risk profile. Most agricultural or tree-based production systems have a typical lifecycle, alternating periods of gain in carbon stocks and periods that carbon is either harvested or decomposed. The ASB team developed the 'time-averaged carbon stock' as an indicator of a land-use system that:

- indicates the average Carbon stock in aboveground plus dynamic belowground carbon pools integrated over the life cycle of the system
- equals the average for that land use system as a component in landscape mosaics if system is not expanding or declining
- equals the average daily C-accumulation rate multiplied by the C-residence time for the various carbon pools (e.g. tree canopy, wood, roots, coarse and fine litter).

The daily rate of C accumulation is remarkably similar across different vegetation types, as a leaf area index (total leaf area per unit gound area) of about 3 is sufficient to capture nearly all energy in incoming sunlight, whether low to the surface as in a grassland or high in the canopy in a rainforest. The primary differences between agroecosystems derive from differences in 'residence time', with the longevity of trees as a first indicator and the residence time of the major dead organic matter sources as a second one (see also box on peat soils).

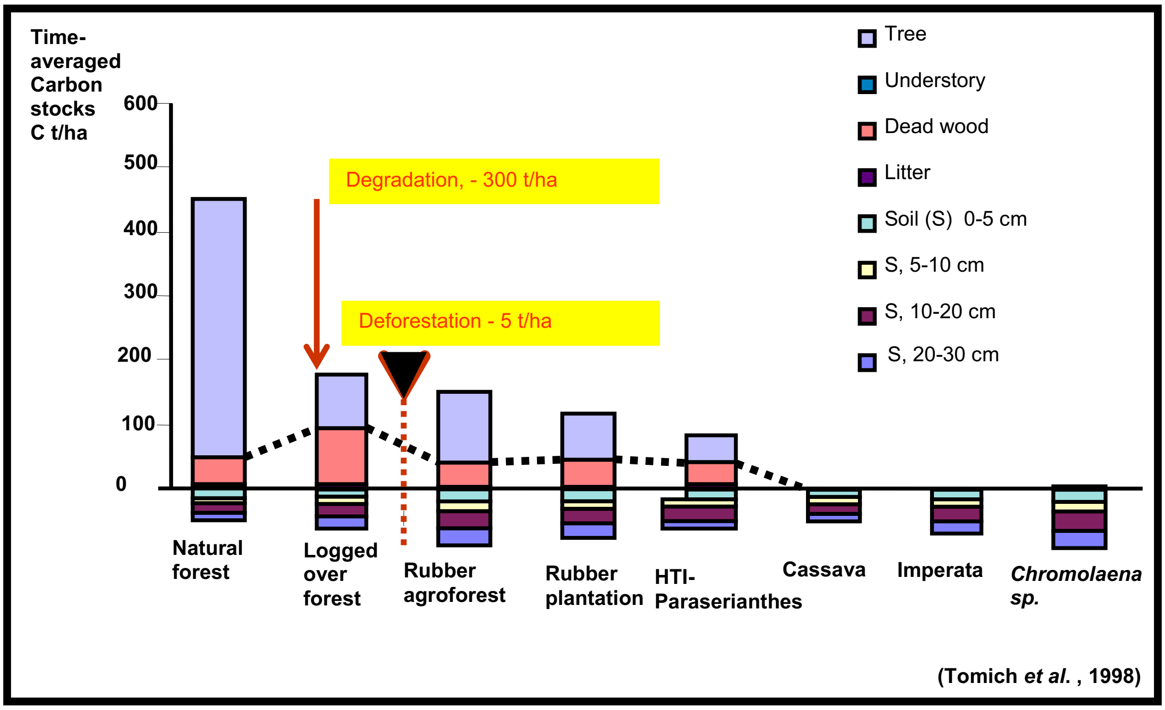
For example, as a first approximation for conditions across the humid tropics, we can expect

- Natural forests to contain 250 t C / ha, accumulated at 2.5 t C / ha /year with a mean residence time of 100 years,
- Agroforests to contain 90-120 t C / ha, accumulated at 3 t C / ha / year) with a mean residence time of 30-40 years,
- Fastwood plantations to contain 50 t C / ha,, accumulated at 5 t C / ha / year with a mean residence time of 10 years.

Sitompul et al. (2001) provides a further discussion of he concept, while Hairiah et al. (2001) provides the methods and Haririah and Rahayu (2007) integrated concepts and methods in a Bahasa Indonesia version.

To illustrate the components of time-averaged carbon stock, Figure 1.1 presents summary carbon stock estimates for major land uses in the ASB site in Jambi, Indonesia, with the carbon stock partitioned into categories of above and below-ground carbon.

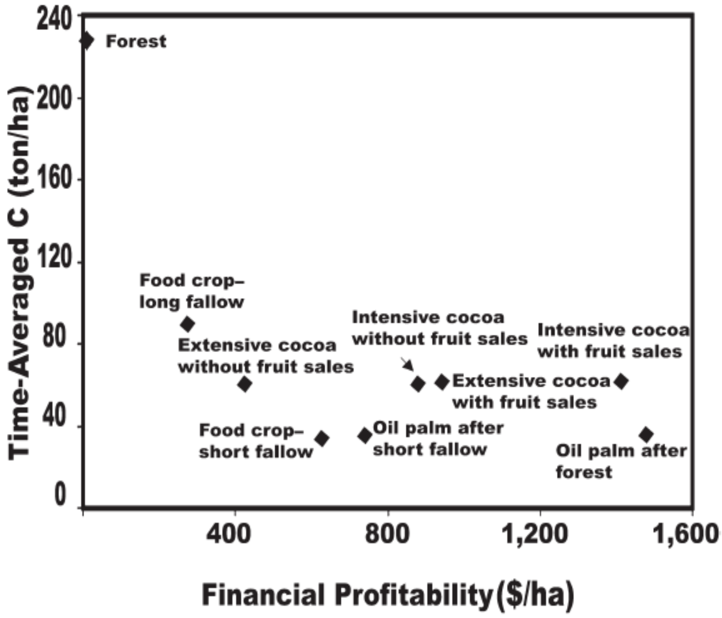
Figure 1.1 - Land use change and C stock at the ASB site in Jambi, Indonesia, 1995)



Potential financial profitability has been calculated for each of the important land uses found in all of the ASB benchmark sites (see Sanchez et al (2005) for a full list of the sites). The profitability analysis considers all establishment costs and all cost and revenue streams over the lifetime of the system. The cost and revenue streams are discounted and summed to produce an estimate of the net present value (NPV). All labour is valued at the local market wage and outputs valued by farm-level prices. Return to land is calculated as the present discounted value of net profits that a farmer would expect to earn from land allocated to a particular land use for a complete production period. In order to compare land use systems with different harvest cycles, the analysis employs a 20-25 year time horizon. The costs and benefits of commercial logging operations that clear forest for agriculture are not included in the NPV calculations in sites where farmers normally do not reap the value of that timber (e.g. Cameroon) (Vosti, Gockowski and Tomich, 2005). The Policy Analysis Matrix approach is used to calculate social-level benefits and costs that explicitly take account of policy distortions and different discount rates.

Combining the results on time-averaged carbon stocks and financial profitability produces an analysis of the tradeoffs associated with different land uses. Results from Cameroon displayed in Figure 1.2 are similar to those found in other sites. That is, the highest profits are associated with the lowest time-averaged carbon stock and the lowest profits associated with the highest carbon stocks. Between these extremes, however, there are a number of land uses that have time-averaged carbon stocks of between 20 and 80 tonnes per hectare and much different levels of profitability. While any disturbance of the forest reduces carbon stocks by more than 60%, there are several opportunities to increase both carbon and private profitability by shifting among other possible land uses. Most notable are conversions from food crop-short fallow to intensive cocoa and cocoa-fruit crop systems. Figure 1.2 displays the carbon – profitability tradeoffs generated for the Cameroon benchmark site (Vosti, Gockowski and Tomich, 2005).

Figure 1.2: Tradeoffs between financial profitability and above-ground carbon stocks of major land uses in the Cameroon ASB benchmark site



Source: Vosti, Gockowski and Tomich, 2005, p.429.

1.3 Objectives

The ASB tradeoff studies provide an excellent starting point for more detailed studies of the opportunities for avoided deforestation with sustainable benefits in the humid tropics. The word ‘opportunity’ is used here to connote three related concepts. One concept is opportunity cost – an important element of the economics of CO_2 abatement through avoided deforestation is the opportunity cost of keeping land in high carbon uses compared to the costs of switching into lower carbon land uses. The other ‘opportunity’ is the prospect for avoided deforestation to be an important approach to reduction of greenhouse gas emissions relative to other mitigation options. The third ‘opportunity’ is the prospect for poor smallholder farmers in the tropics to benefit from the new global interest in avoided deforestation.

This report presents an analysis of the opportunity costs of reduced CO_2 emissions through avoided land use change in five sites across the tropical forest margins, including ASB benchmark sites in Indonesia, Cameroon and Peru. Previous work in the East Kalimantan site was conducted by the Center for International Forestry Research outside of the ASB partnership structure (Dewi, Belcher and Puntodewo, 2005). Similar analysis is still in process in the Philippines and planned for ASB sites in Brazil. The results of the opportunity cost analyses are aggregated into a two-dimensional chart with a vertical axis plotting opportunity costs in terms of US$ / tonne of CO_2eq and a horizontal axis plotting amount of avoided CO_2 emissions in the whole area. With strong assumptions about transaction costs and property rights, that relationship can be interpreted as a potential supply curve of CO_2 abatement from avoided deforestation.

A distinctive characteristic of this study is the level of detail that it has for the geographic size of the sites that it covers. All of the five sites are large, approximating the size of the smaller countries of Europe. Useful interim products of the study are land-use characterizations for the sites, land-use change analyses summarized into land use transition matrices, and carbon stock inventories and changes since the 1980s (measured in terms of time-averaged carbon stock). Also, because many of the changes have resulted in shifts from lower to higher carbon values, the study also shows that there is potential for large-scale win-

win solutions (higher carbon and higher farm profits) through the expanded use of agroforestry systems. Extensions of the analysis show the high sensitivity of the results to the discount rate.

It is important at this point to recognize the limitations of the current study. First, the study focuses only on land use change in mixed use landscape mosaics as a source of CO_2 emissions, not on the degradation of forests through selected logging, fire or other management practices. In other words, it focuses on the first D of REDD. Second, the study has limited geographical scope. While ambitious compared to other studies, it considers only 5 sites across the humid tropics. Even in Indonesia, where 3 of the sites are located, there would be great benefit from replicating the study in all, or at least several other provinces. An important next step would be to replicate the study in provinces with large areas of peat forest. Beyond Indonesia, every country that wants to formulate a strong case for international investment for REDD should undertake this kind of analysis for a representative set of sites. Third, the study does not explore the numerous institutional issues – international, national, local -- that would need to be addressed in the design and implementation of a functional REDD mechanism. Numerous other papers have been written, and volumes will be written in the future, on these topics. On the other hand, very few studies can provide the strong empirical base of the ASB partnership. Fourth, the study of opportunity costs is retrospective rather than prospective. It examines the geographic patterns and economic implications of deforestation from 1990 to present. It is likely that both the proximate and underlying causes of land use change in the tropics will change in the future. As indicated in the text box above, there is considerable concern that rising demand for biofuels will provide a new round of deforestation.

Field Site at Degi Harja, East Kalimantan, Indonesia (photo: ASB)

View on the north side of the forest with coffee gardens in the foreground. of Bukit Rigis, Lampong, Indonesia. (Photo: Bruno Verbist)

Slash-and-Burn to replant rubber, Jambi lowlands near Muara Bungo, Indonesia (photo: Tom Tomich)


Flooding in inland valley system aggravated by road construction and farming. This makes up approximately 8-10% of total land in the benchmark area. Near Akok, Cameroon (Photo: P. Akong Minang, ASB)


Multistrata Cocoa farm South of the Cameroon sites (Photo: P. Akong Minang, ASB)

Multistrata agroforestry in Pucallpa, Peru
(Photo: Jan Beniest, ICRAF)

Field cleared for agriculture at ASB site in Pucallpa, Peru
(Photo: Jan Beniest, ICRAF)

2. Site Descriptions

> *Forest-related mitigation activities can considerably reduce emissions from sources and increase CO_2 removals by sinks at low costs and can be designed to create synergies with adaptation and sustainable development (high agreement, much evidence)*
> IPCC. 2007. Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

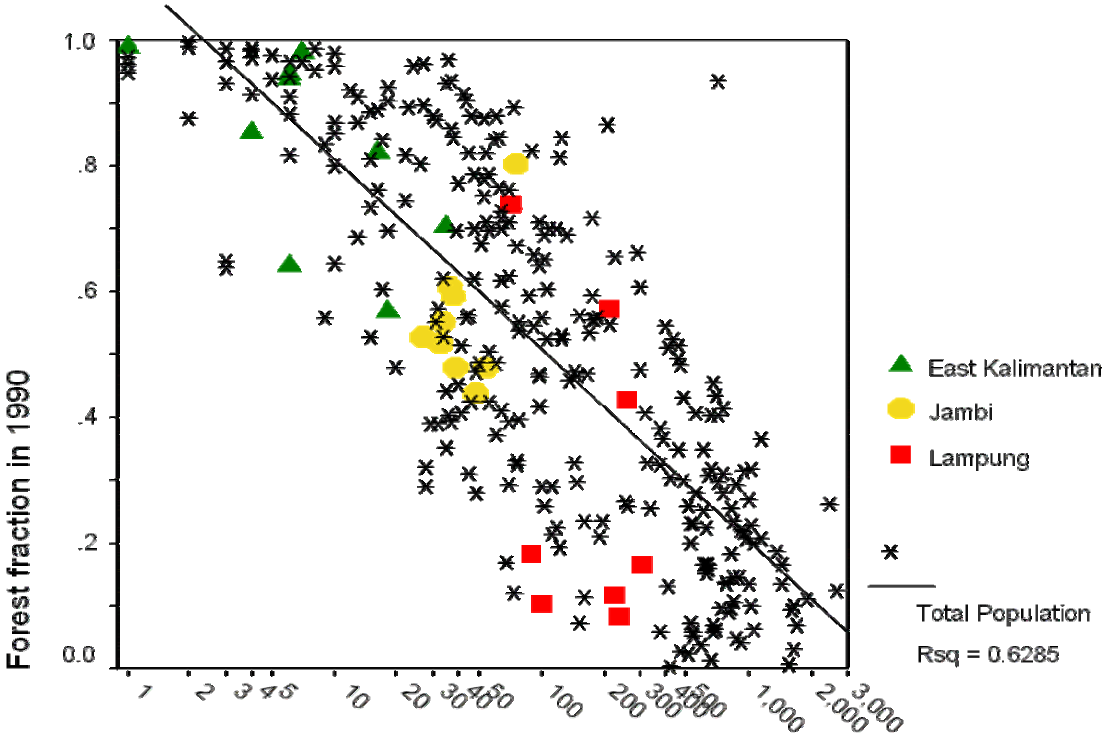
This report is based on research conducted at five sites across the tropical forest margins that represent active areas of deforestation, selected from a network of ASB sites within the tropical and sub-tropical moist broadleaf forest biome. The sites correspond to a wide range of biophysical and socio-economic conditions under which slash-and-burn agriculture occurs. The sites represent a gradient of forest transition ranging from traditional shifting cultivation to intensive continuous cropping and degraded lands, driven by a range of proximate and underlying factors. Section 2.1 provides a brief overview of the national context for land use change, while section 2.2 examines the issues at the site level.

2.1 National and regional-level context

In Cameroon, rapid population growth coupled with-the expansion of low productivity fallow based food systems targeting both subsistence and commercial purposes appears to be the dominant proximate cause of deforestation – which currently stands at 0.6% annually. Cocoa is the predominant permanent agricultural system in the forest zone of Cameroon and its expansion was encouraged by several large extension efforts in the 1970s and 1980s. Cocoa expansion in West Africa has been, and remains, one of the principal causes of the near disappearance of the Guinea tropical forest biome, which, with only 10% of the original forest remaining, is among the most critically threatened global biodiversity hotspots. However, cocoa systems in southern Cameroon, which account for approximately 3,000 $km^{2,}$ are the most heavily shaded in West Africa and as such are indistinguishable from secondary forest even when using the highest resolution satellite imagery. Thus cocoa production has been more an agent of forest degradation than deforestation, especially when systems are established by planting into thinned forest. There is also evidence that macroeconomic policies and demographic & economic trends have shaped the nature of deforestation. Evidence from satellite image analysis shows that during the economic boom of the early 1970s and 1980s, the rate of deforestation slowed as people migrated into cities for jobs. When commodity prices (cocoa and coffee) slumped, and government agricultural input subsidies were withdrawn in the late 1980s and early 1990s, an economic crisis set in, which triggered mass return of working-age people from the cities to the rural areas. This reverse migration increased deforestation rates considerably in rural areas as returnees turned to food crop production to sustain their families (Sunderlin et al., 2000).

In Indonesia, forest conversion is driven by a range of factors and actors. Local smallholder farmers, migrants, loggers, large-scale tree crop estates (including industrial timber plantations) and government-sponsored resettlement schemes have all played roles in forest conversion in Jambi, Lampung and East Kalimantan (Tomich et al., 2005). Decades of economic growth have created a powerful class of large-scale land operators whose interests frequently clash with those of smallholders. The 1997 collapse of the country's currency made the conversion of forest land to the production of export tree crops such as oil palm, rubber, cocoa and coffee even more attractive. Competition between migrants, indigenous people and large investors in farming characterize driving forces of deforestation in the more-densely populated Jambi and Lampung provinces on the island of Sumatra. Logging is a dominant driver of deforestation in East Kalimantan where deforestation has been occurring at a somewhat slower pace. Figure 2.1 shows relationships between population and fraction of forest cover in the districts of Indonesia. Districts in East Kalimantan generally have low population density and high forest cover; those in Lampung have high population density and low forest cover, while Jambi districts are between the two extremes. Statistically, a logarithmic relationship between population density and forest cover accounts for 63% of the variation on forest cover and can be used as first indicator. There is also for further analysis of the districts that are above or below this general trend (Murdiyarso et al., 2006).

Figure 2.1 Relationships between population density and fraction of forest cover in Indonesian districts



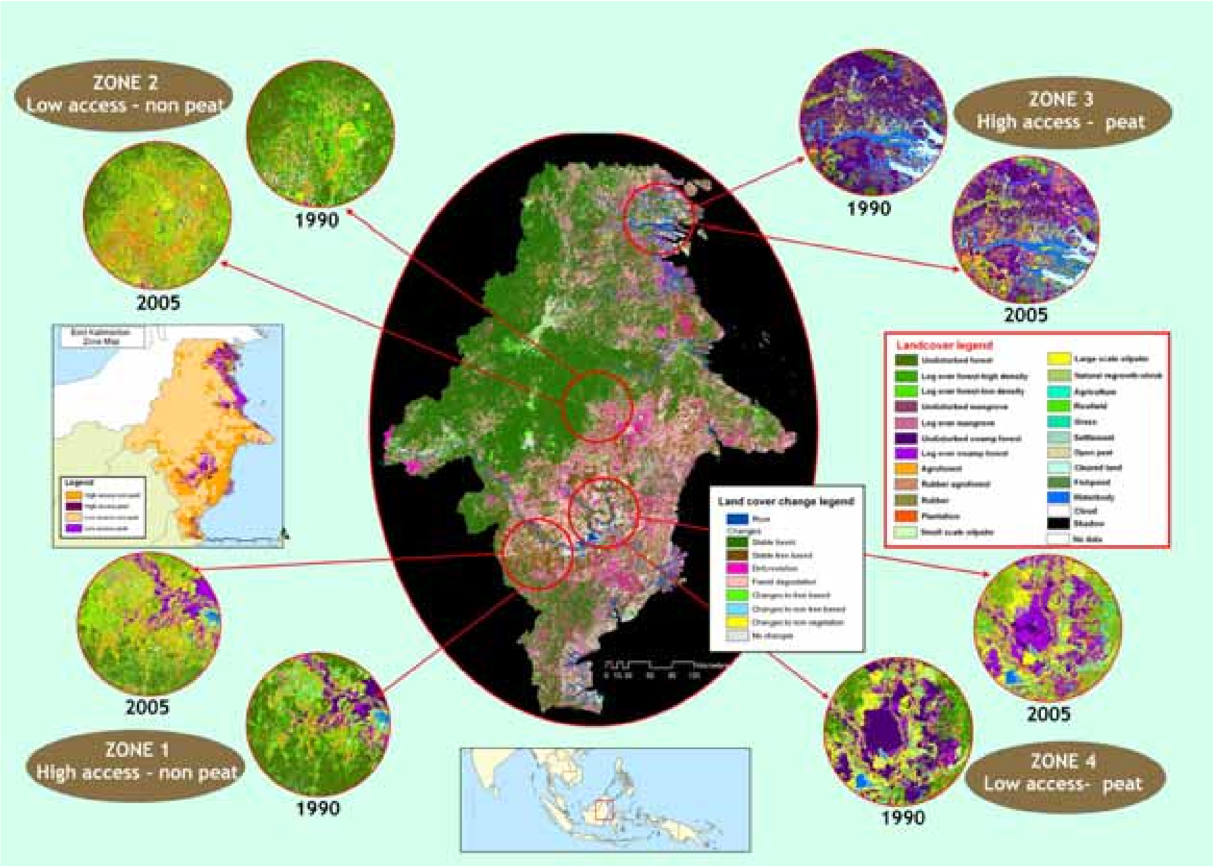
Source: Murdiyarso et al., 2006.

In Peru, macroeconomic policy has impacted the development of the livestock sector, which has had a direct influence on forest conversion. In the 1960s and 1970s, the Belaunde and the Velazco administrations deeded large areas in the Amazon to farmer cooperatives for logging and cattle ranching. These governments also promoted subsidies, price controls and tariff protection. Hence huge logging and livestock associated deforestation in those years. Between 1985 and 1990, the Garcia government responded to economic instability (inflation) by subsidizing credit, fertilizers and chemical inputs and establishing high floor prices for many crops. These policies created incentives for rice and maize production in the Amazon. As a result, farmers increased cultivated areas, thus increasing deforestation rates in the period 1985-1990. Successive governments have eliminated agricultural credit and price supports, thereby reducing large scale agricultural expansion and associated deforestation. This Andean-Amazon context starkly differs from that of Brazil where government support has been more generous and consistent (Hecht, 1993; Scatena *et al.*, 1996; Vosti and Witcover, 1996).

2.2 East Kalimantan, Indonesia

The province of East Kalimantan spans 220,400 sq km, an area the size of the UK. It includes several river systems and most of the economy and transport is still based on these rivers. Roads are only important for transport in the coastal zone. It has high ethnic diversity, based on a complex history of migration and connections with the main centers of power. Rural population densities at district level vary from 1 – 40 persons per square kilometre. As a result, the province is about 79% forested. Logging and harvesting from forests is the dominant economic or extractive use of forests in East Kalimantan. A few oil palm plantations were established, but remain mostly unproductive and abandoned due to conflicts between investors and local groups. Inland rural people in the area practice crop-fallow rotations on plots for one or two planting periods, then allow the land to return to fallow or to become a rattan or fruit garden; rubber agroforests are not as common as it in West or Central Kalimantan.

Figure 2.2 Land use change in East Kalimantan



Source: Dewi, 2007.

With the largest and most intact remaining lowland rainforest on the Island of Borneo, East Kalimantan harbours very rich biodiversity. It harbours 11 primate species including orang-utans, proboscis monkeys, gibbons and other rare, threatened and endangered species such as the clouded leopards, sunbears and *banteng*, which are similar to water buffalo.

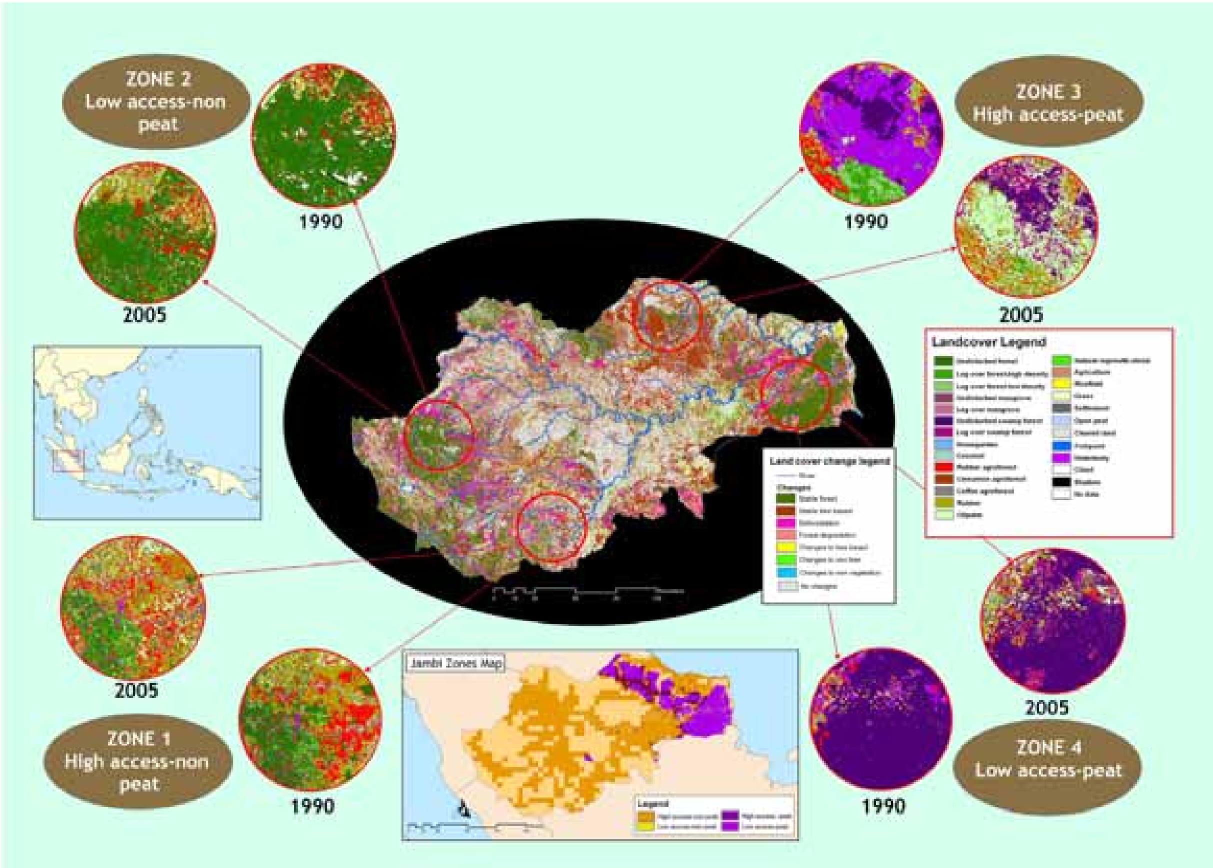
The Upper Kelay Watershed in East Kalimantan is also home to Borneo's earliest indigenous people, the Punan Dayak. The Punan Dayak philosophy of viewing the forests as sacred place is one of the key reasons why the Kelay watershed has not yet been ravaged by Illegal logging (TNC n.d.).

2.3 Jambi, Indonesia

The Jambi province in central Sumatra in Indonesia has an area of about 55,000 km^2. Jambi represents the moderate or middle area in the gradient of forest transition defined by the three sites in Indonesia. Population density is about 39 persons per square kilometre and about 45% of the area is highly accessible by road or water. There is active conversion of forests into perennial crops of high economic value (mostly oil palm and rubber) in the Jambi province. Total area under rubber cultivation in Jambi in 1993 was 503 km^2, most of which is 'jungle rubber' - i.e. extensive rubber agroforests. Government supported and spontaneous transmigration has been active in the area, thereby increasing forest conversion to agriculture and settlements. Hence, only 34% of the province remains forested. While 64% of Jambi land remains categorised as state forest land, in practice, the greater part of the forest land is used for rubber agroforests and other forms of agriculture.

Deforestation in Jambi aggravates a serious problem of loss of biodiversity in a habitat that is unique in the world. Sumatra has the most mammals (210 species) of any Indonesian island, sixteen of which are endemic. Four endemic mammals in Sumatra are listed on the IUCN Red List of threatened Species and on the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Most of Sumatra's endemic plant species are found in lowland forests below 500 metres. Birdlife International has Identified more that 34 Important Bird Areas on Sumatra, of which 54% are outside protected areas and 18% are in critically threatened lowland forests.

Figure 2.3 Land use change in Jambi



Source: Dewi, 2007.

Logging and the rubber processing industry (crumb rubber) represented almost all exports (99%) from Jambi province in 1993. Small holder rubber contributes significantly to this industry. Virtually all smallholder households interviewed during the ASB site characterization surveys in Jambi are engaged in agriculture. Less than 10% of households of local farmers and spontaneous migrants engage in non-agricultural activities. On the contrary, 75% of transmigrant households reported non-agricultural activities (trading, services and paid), though not as a main occupation. More than 70% of household heads interviewed in Jambi did not complete primary school. This rate was particularly high (95%) among local people in the Bungo Tebo area.

Box 2.1 Tropical Peatlands at risk – how we are draining our carbon sinks for short term gain

In most forests there is a balance between the capture of CO_2 from the atmosphere in the formation of plant matter, and the breakdown of organic matter through decomposition, and most of the existing carbon stock is in the living biomass. Under conditions that slow down decomposition, however, such as found in cold climates, and/or where water reduces the availability of oxygen together with low nutrient availability in the tropics, peat can be formed. Because of this lack of oxidation, peatlands can be carbon sinks for thousands of years, storing undecomposed organic matter. The carbon can be stored for as long as the basic conditions of low oxidation remain intact. However, when peatlands are drained, their large carbon stocks will lead to massive CO_2 emissions, that can release during a few decades what took thousands of years to accumulate. Worse, if the peatlands burn, these emissions can take place in a matter of days. Peat can, after extraction and drying, be used as a fuel, but one that provides high emissions per unit energy released.

Because of their low nutrient availability and wet conditions, peatlands have not been very attractive lands for agriculture, except for small-scale conversion to a wetland crop such as rice. With adequate fertilization, however, peatlands can be technically suitable for crop and tree production, provided that the water content is controlled by drainage. This type of use, however, leads to high carbon emissions.

Indonesia contains about half of all tropical peatlands, and over the last decades substantial areas of peat were cleared of their natural vegetation and replaced by oil palm, fastwood plantations for the pulp and paper industry, for large scale irrigated rice development or for small-scale local agriculture. Such conversion leads to emissions at the time of clearance, especially if fire is used as tool, but the subsequent drainage also increases the vulnerability to the spread of wildfires, often escaped from land clearing fires elsewhere. Beyond fire, the drainage leads to emissions due to oxidation; the deeper the drains have been cut, the higher the emissions. Current practice indicate the deepest drainage and thus highest emissions when oil palm plantations are established.

In a report first released at the 2006 UNFCCC meeting in Nairobi, Wetland International estimated that emissions from peatlands in Indonesia might amount to 2 giga ton (= 2 billion ton) of CO_2 from fire plus 600 million ton die to oxidation after drainage. These figures place Indonesia as the third largest global emitter of CO_2, and have been subject to disbelief and controversy. The current assessment has sought to test the various assumptions underlying these calculations and provide a more detailed analysis of land use change in both the peat and the adjacent mineral soil domains.

Apart from the large scale plantations, part of the smallholder agricultural systems also lead to high emissions per unit area. In parts of South Sumatra, rice is grown in an opportunistic fashion using years with long dry seasons, in what is locally known as the "sonor system". Converting peat forests through slash and burn increases soil fertility and provides short term economic gain, but emissions are very high when compared to the relatively small economic gains made from the rice. We estimate that with one fire cycle in 6 – 8 years and a burning depth of 15-20 cm, on average 2.5 cm peat is burnt per year, translating to emissions of about 55 t CO_2/ha/year (Agus and van Noordwijk, 2007).

The results of our study in the three provinces East Kalimantan, Jambi and Lampung, which on average contain 5% of peatland, and which cover 7% of Indonesia's peatland, confirm the importance of these areas for the total CO_2 emissions. Our results suggest that reduced peatland conversion may be an easy target for REDD mechanism since conversion brings relatively low economic benefits. Rehabilitation efforts have also been cost effective where drainage canals were blocked and wetland conditions restored. A major issue, however, is that current versions of REDD rules will only apply to further deforestation, not to the opportunities to reduce emissions from peatlands that already lost their forest cover. We estimate this 'eligibility' issue to affect about 50% of Indonesia's land-based emissions.

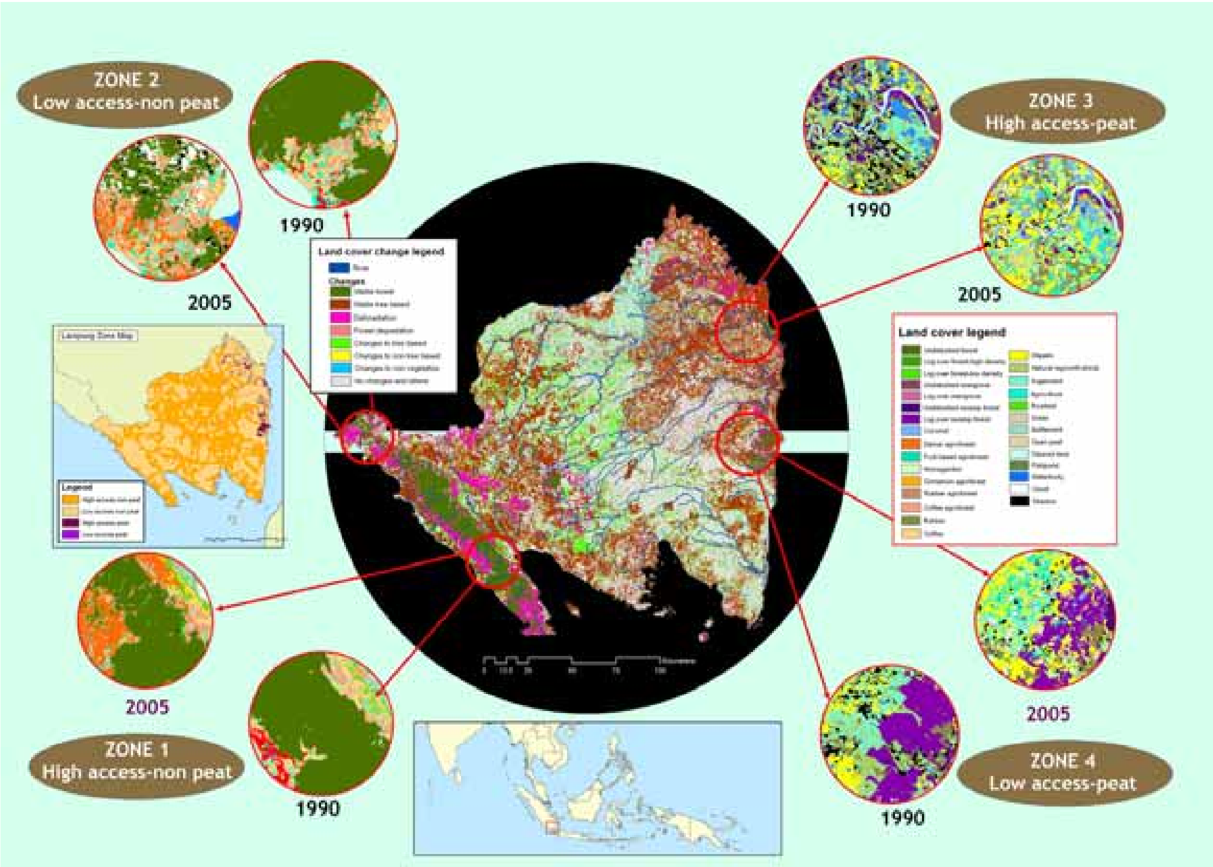
2.4 Lampung, Indonesia

Lampung province is at the southernmost tip of Sumatra and is close to Java, with which it has historical links. More than a century of government-sponsored and spontaneous migration from densely populated Java has essentially transformed Lampung province into 'North Java', with only a minority of the population tracing their roots to the province itself.

Only 8% of Lampung province is forested, mostly in the mountain range in the west (around Bukit Barisan Selatan National Park). Most of the commercial logging took place in the 1970s, followed by conversion to large-scale plantations (incl. sugarcane, pineapple) and resettlement, with cassava as a major crop in the lowlands. On the more fertile soils ion the foothills and mountains, coffee is the main crop, with waves of migration linked to peaks in coffee prices. 52% of the province is highly accessible by road.

Indigenous Lampung people, who live along the rivers, still have their semi-permanent food crop production plots on flooded river banks. They no longer practice shifting cultivation, but still maintain old 'jungle rubber' gardens on the margins of Sumatra's rubber belt. Transmigrants have mostly cultivated valleys and depressions where paddy-rice could be grown. However, owing to droughts, soil degradation and difficult conditions, there has been an exodus from the region. Evidence also suggests that more and more indigenes prefer making a livelihood outside agriculture.

Figure 2.4 Land use change in Lampung



Source: Dewi, 2007.

2.5 Ucayali, Peru

The Peruvian Amazon site is the Ucayali Department. The Ucayali comprises of a large portion of the Aguaytia river watershed covering approximately 1.5 million ha. This area corresponds to an area about 80% the size of El Salvador, but only hosts about 5% of that country's population. Population densities range from 0.22 persons per km^2 in the more remote eastern province to 9.3 persons per km^2 in the Coronel Portilio Province, which contains the capital city, Pucallpa. Average population density is 4.1. The Ucayali borders the state of Acre in Brazil. In many areas, road and river access can be difficult.

The dominant land cover is forest, including nearly pristine forests and selectively logged forests. Besides logging, extractive activities also take place in these forests. Shifting cultivation mosaics constitute the next most important land use in Ucayali. These mosaic lands normally consist of various rotational stages of annual food crops such as rice, cassava, plantain or beans. Thereafter the land is left to fallow. These fallows also constitute an important part of the landscape. If and when cattle are available, most fallows are converted to pasture lands. Approximately, 46% of farmers have cattle, while almost all farmers aspire to get some. However, most small ranches (92%) have mixed systems that include annual crops. About 2000ha in Ucayali is also planted with oil palms. More than 300 families depend on these oil palm plantations as their principal income source.
The Ucayali department, like most of the greater Peruvian Amazon, is experiencing urbanization. In 1996, only 35% of the Ucayali population lived in rural areas. According to the Ucayali agricultural census (1996), 21,245 households with approximately 10800 household members cultivated about 1.9 million ha. The paved Lima-Pucallpa road serves as an important means of access to the rest of the country for the marketing of forest and agricultural products (White et al., 2005).

Figure 2.5 Land Cover in the Central Peruvian Amazon, 1990

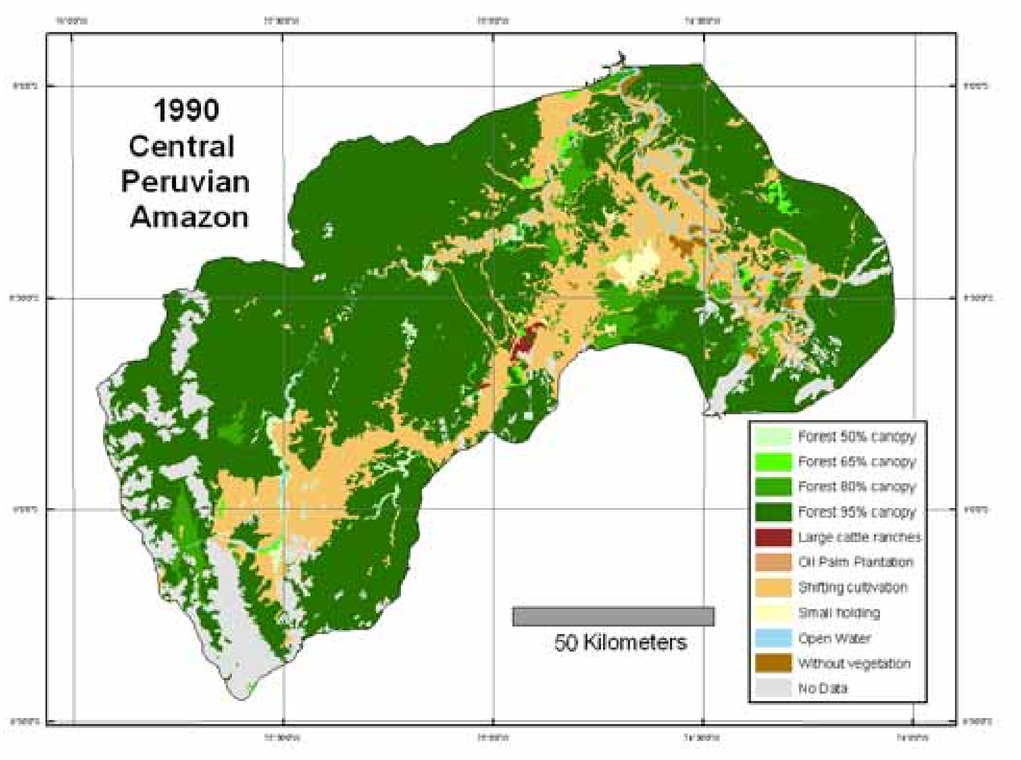


Figure 2.6 Land Cover in the Central Peruvian Amazon, 1998

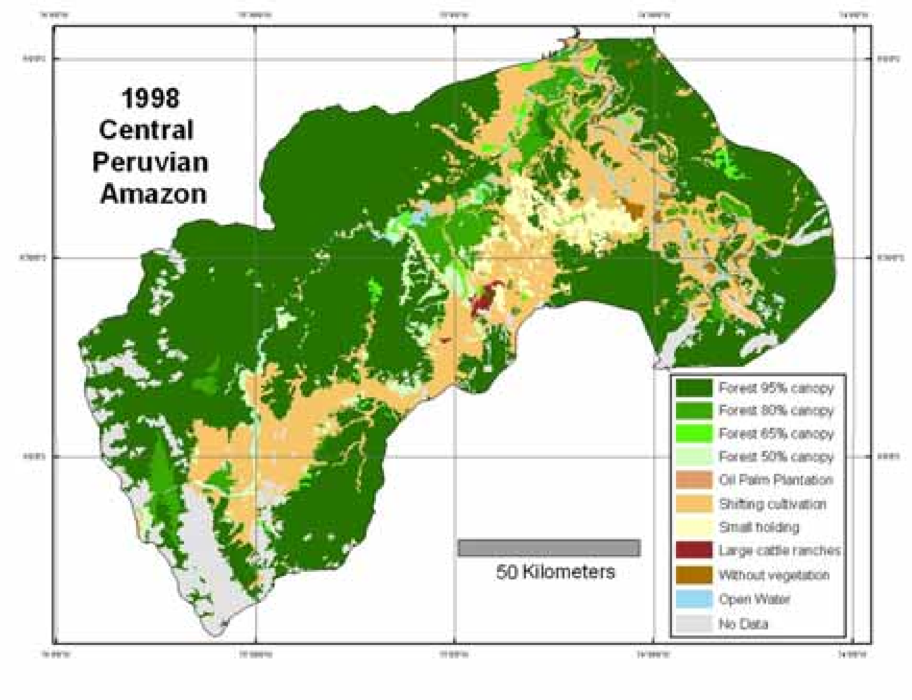
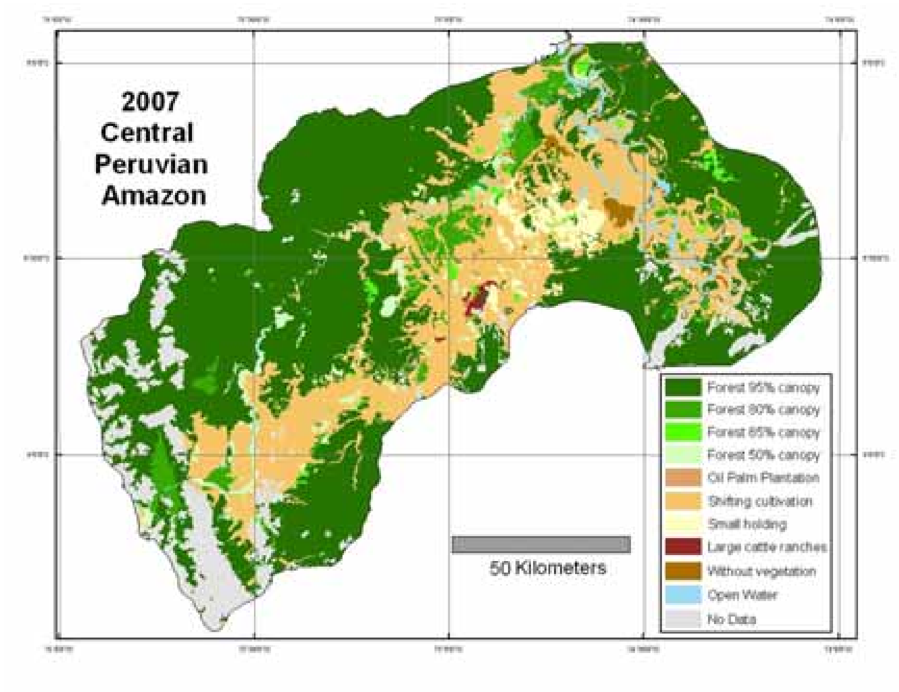


Figure 2.7 Land Cover in the Central Peruvian Amazon, 2007



2.6 Central plateau of Cameroon, Guinean-Congolian Forest Margins:

The Forest Margins Benchmark Area of Southern Cameroon straddles the transition from the Guinean forests of West Africa and the Congo basin and was selected to represent the conditions of tropical forests in both biomes. Located between latitudes 2° and 4° N, it covers an area of 1.54M ha (roughly the size of the United Kingdom) (place map of benchmark about here). This area was purposively defined over gradients of population density and market access with population varying from 70 to 200 persons km^{-2} in the northern portion to 5 to 30 persons km^{-2} in the southern portion (Gockowski et al., 2005). Natural climax vegetation comprises of semi-deciduous forests in the north transitioning into dense humid Congolese forests interspersed with evergreen Atlantic forests in the middle and southern parts (Letouzey, 1988). Only about 4% of the land in the northern portion remains as natural forest, while about 59% of the land cover in the southern end remains as intact/ primary forest.

Box 2.2 Cocoa Agroforests in Cameroon: a potential option for reducing emissions

Cocoa is the primary source of farm income in the ASB benchmark area in Cameroon, with food crops grown mainly to meet subsistence needs. However, results from this study shows that cocoa agroforestry systems have changed very little. Instead mixed annual subsistence food crops (groundnut-cassava and melonseed-plantain) cultivation accounted for more forest conversion than any other land use in Cameroon between 1984 and 2001. Macroeconomic trends explain the land use change trajectories influencing deforestation in Cameroon. A series of policies in Cameroon influenced crop preferences of small-holder farmers, with major implications for deforestation rates. Between 1977 and 1985, the country enjoyed a boom fuelled by exports in petroleum, cocoa and coffee. Then in the late 1980s, the economy slumped due to a fall in commodity prices in the world market. In response to the economic crisis, the government stopped subsidies to agricultural inputs and halved commodity prices offered to farmers in 1989. In the early 1990s government followed on with drastic cuts in public sector employment and wages. Finally Cameroon's currency was devalued in 1994 by 50%. Shortly after, government liberalized cocoa marketing. These shocks greatly influenced rural decision making.

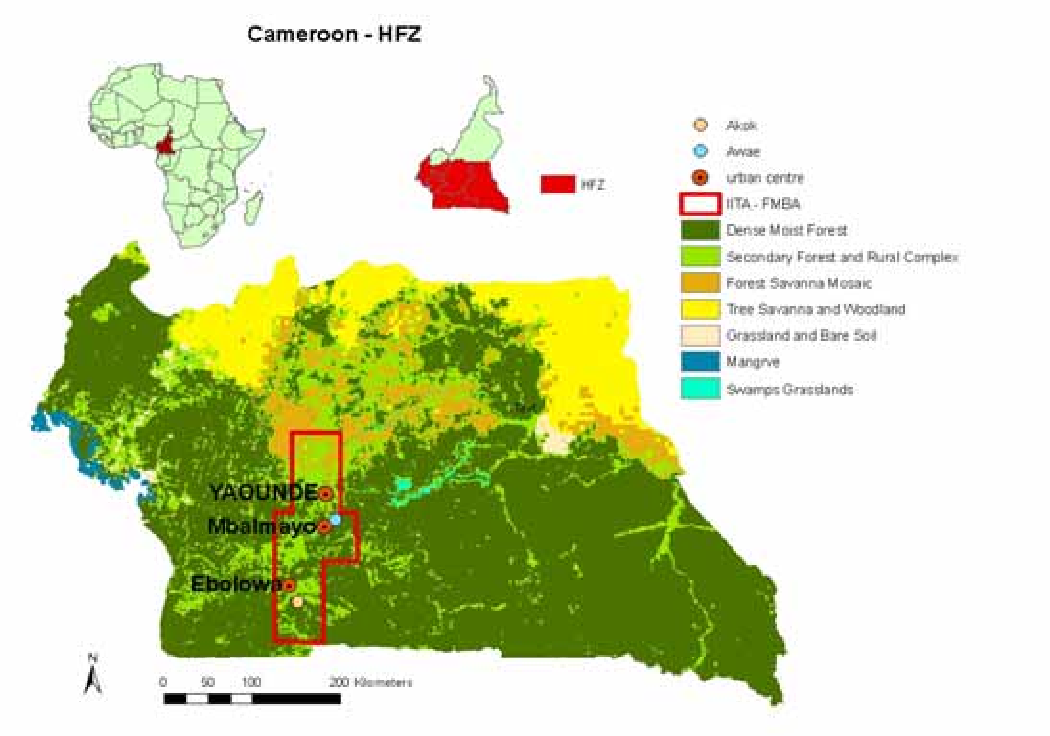
Evidence from satellite image analysis show that during economic boom in the early 70s and 80s deforestation slowed down as people migrated into the cities for jobs. And when the economic crisis set-in they returned to the villages and preferred to create more annual food crop farms to sustain their families, given that cocoa was no longer very attractive (Sunderlin et al., 2000).

Though mixed farming was favoured by small-scale farmers through these shocks, cocoa agroforests and or similar systems were found to be potentially useful for REDD strategies in the Guinea forests of West Africa and the Congo basin. First, these systems avoid the most emissions of all the land uses in Cameroon because the majority of them are planted under thinned forest and not after a deforestation episode of slash-and-burn. The cocoa shade canopy often includes a productive component of fruit and economic trees. Secondly, social profitability on an annual, per hectare basis showed cocoa agroforests was more lucrative than slash-and-burn systems ($1,700 vs $ 300-600). This means lower opportunity costs, hence it can be considered a potentially cost effective means of reducing global emissions.

Twenty-eight percent of the total area across the benchmark site was estimated to be in agricultural use (including fallow fields) in the late 1990s with significant spatial correlation with rural population densities. The predominant land use system is cocoa, accounting for 48% of the total productive agricultural land use. Rotational food crop-fallow systems account for the remainder of agricultural land use in the following order: mixed groundnuts-cassava fields, plantain/melon seed fields, and intensive mono-crop fields (mostly in areas with higher population growth and access to market institutions serving the burgeoning demand of Yaoundé, an urban center of approximately 2 million located in the northern portion of the benchmark area.

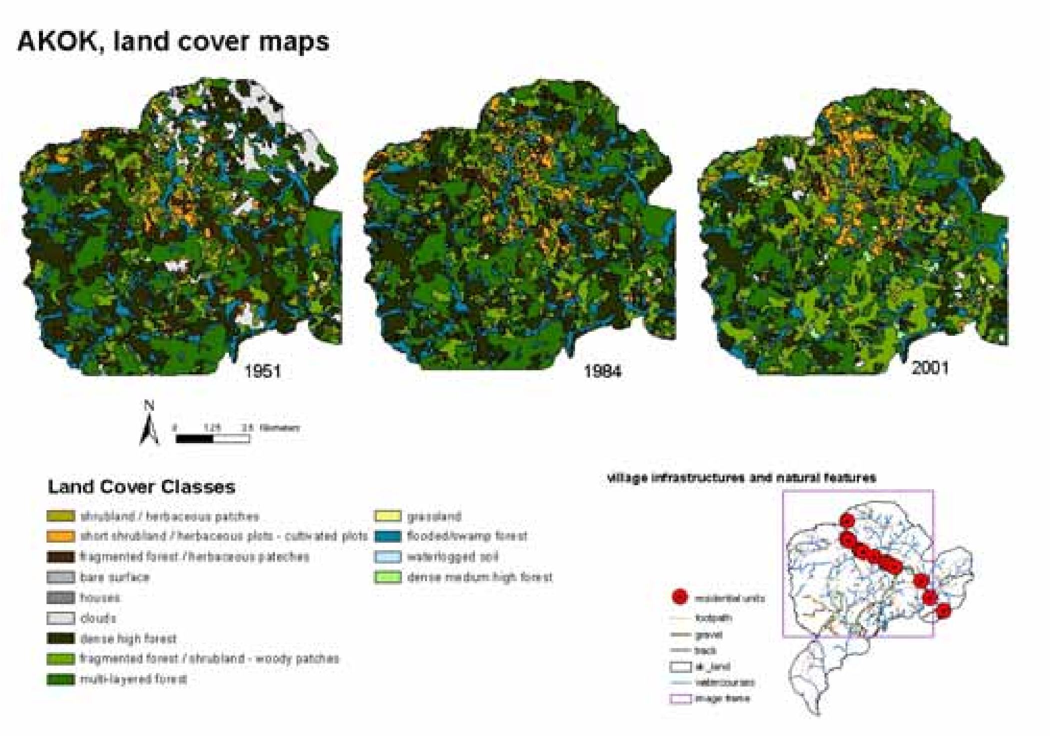
High fauna and flora diversity characterize the benchmark area in Cameroon. Over 200 plant species per $1000m^2$ transect has been documented, which is among the highest recorded plant diversities in Africa (Garland 1989). Of the 250 mammalian species in Cameroon, 162 exist in moist forest, with 32 of these species found only in this habitat. Evidence of western lowland gorillas has been recorded in wildlife transects conducted by ASB in the benchmark. And the isolated rainforest rivers along the Atlantic coast contribute to one of the highest freshwater fish biodiversities in the tropics at 490 species which includes many endemics.

Figure 2.8 Location of Cameroon Sites



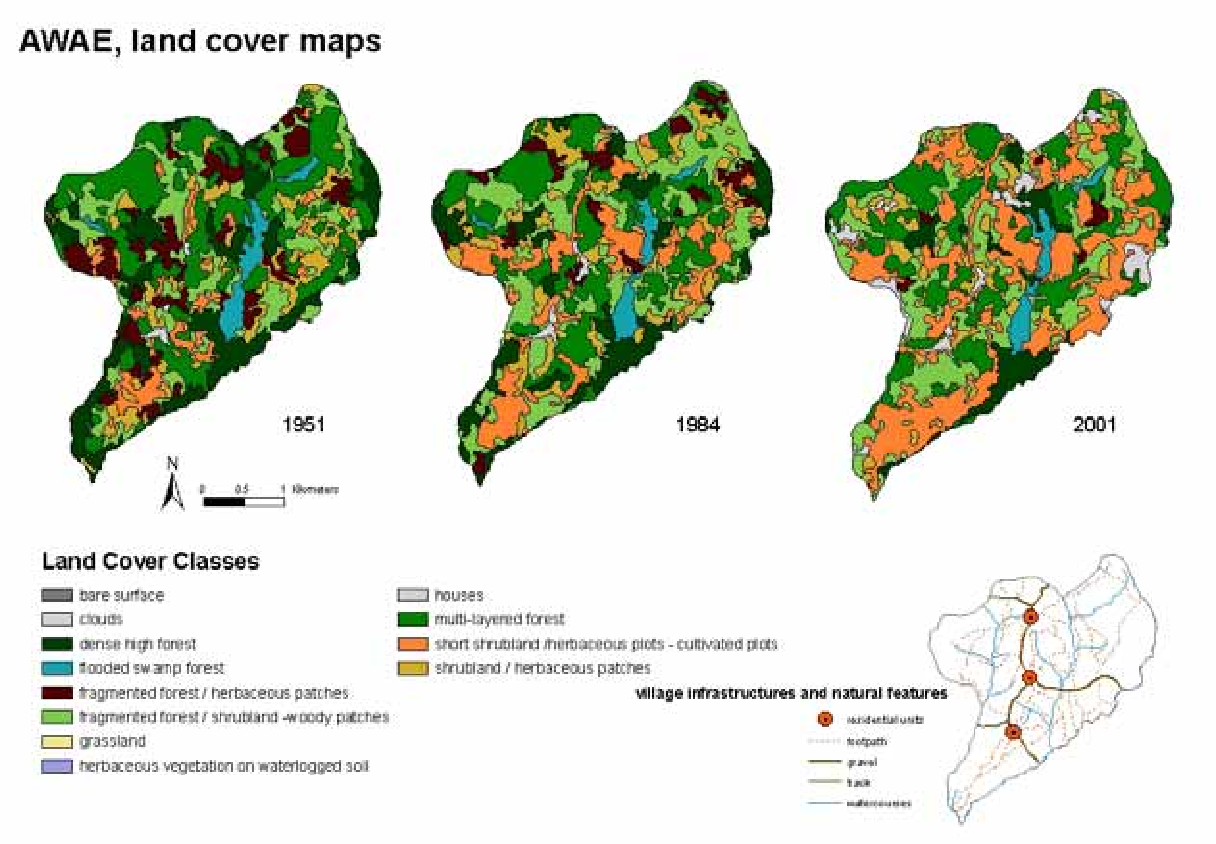
Source: Robiglio, 2007

Figure 2.9 Land cover maps, Akok Cameroon



Source: Robiglio, 2007

Figure 2.10 Land cover maps, Awae Cameroon



Source: Robiglio, 2007

Inhabitants of the benchmark area have since colonial times relied on cocoa as the primary source of cash income and food crops for subsistence needs. There is also significant reliance on natural resource-based activities, such as bush meat hunting and collection of non-timber forest products. Local rural markets are poorly developed and most households are still largely independent of markets for the bulk of their food consumption. Small market surpluses from the traditional mixed food crop systems usually go to the city of Yaoundé where rapid demand growth has spurred the development of intensified commercial cropping systems in some areas (Gockowski and Ndoumbe, 2003).

The current study is focused on two benchmark communities on the Central plateau of Cameroon at an elevation of 400 to 500 m. Akok is a Beti-Boulou village, located about 200 km from the urban center of Yaoundé in the southern portion of the benchmark. Rural population density in Akok is low and as a result farmers have more land than they can crop given current technology. The main source of cash is provided by cocoa which is grown in an extensive low input, low yield production system with a high degree of forest trees retained. In addition to cocoa there are two principal annual cropping systems—the groundnut-cassava mixed food crop field which tends to be cropped following a short fallow of 3 to 5 years, and the melonseed-plantain field which is planted into long bush fallows of 10 to 20 years. Both of these cropping systems are predominantly subsistence in nature with only small surpluses marketed. The second community, Awae, is a Beti-Ewondo village about 35 km south of Yaoundé. Rural population density is moderate. As in Akok, cocoa is the most important source of cash income but some households have turned to commercial food production for the Yaoundé market. The groundnut-cassava field is, as in Akok, the household's chief food supply. Cocoa production in Awae includes the secondary production and marketing of fruits (the fruits of mangos, avocados, *Dacryodes edulis*, and citrus) which augments the productivity of the cocoa production system considerably.

Table 2.1: Summary information on the sites

Characterisation Parameter	Indonesia			Peru	Cameroon
Province / site	Jambi	Lampung	East Kalimantan	Ucayali	
Dominant Original Vegetation	Tropical moist forest	Tropical moist forest	Tropical moist forest	Tropical moist forest: Semi-deciduous forests	Tropical moist forest: Semi-deciduous and moist evergreen forests
Main meta land uses	Natural forest, rubber agroforests, coffee agroforests, oil palm, tea, coconut	Natural forests, coffee agroforest, coconut, dammar agroforests, fruit based agroforest, homegarden	Forests, oil palm, rubber agroforests, mangrove, rice fields,	Natural forests, simple tree crop systems (oil palm, crop / fallow systems, annual crops and pastures	Natural forests, complex cocoa agroforests, mixed food crop-short fallow mosaics, plantain/ melon seeds, intensive mono-crops, fallows
Population Density (Persons km^{-1})	39	174	2-39	3-5	10-120
Farm size (ha $household^{-1}$)	5	2-5	5-10	30-100	5-80
Agricultural Wages (US$ day^{-1})	1.67	1.67	1.67	0.22-9	1.73
*Population below US $1/7 day (1990-2004) %	7.5	7.5	7.5	12.5	17.5
*Adult Literacy (% Ages > 15) 2004	9.4	9.4	9.4	12.3	32.1
* From Human Development Reports 2007 Source: Table is updated from Tomich et al 1998					

3. Methods

> *A Joint attack on climate change and poverty needed, Al Gore tells audience at UN "The old divide between North and South, between developed and developing, is now obsolete…. We must link poverty reduction with the sharp reduction of carbon dioxide emissions," he noted, calling for a plan of attack like that of the Marshall Plan, the post-World War II European reconstruction initiative of the US – to tie the struggles against climate change and poverty."* (United Nations News Centre coverage of the speech by Al Gore to World Leaders at the United Nations High-Level Event on Climate Change, 24 September 2007).
> http://www.un.org/apps/news/story.asp?NewsID=23942&Cr=climate&Cr1=change

The opportunity cost analysis presented in this paper has five main inputs for each site: (1) clarification and description of major land uses; (2) calculation of time-averaged carbon stocks for the major land uses; (3) calculation of the private and social profitability of the land uses in terms of discounted net present value; (4) land use characterization and land use change analysis; and (5) processing this information into a two-dimensional graph charting the opportunity costs of avoiding deforesting land use changes against volume of CO_2eq emissions.

Section 1.2 of this paper above describes the methods that the ASB partnership has devised and used to address inputs (1), (2) and (3). Most of the information that was generated on major land uses and time-averaged carbon stocks in studies conducted in the late 1990s and early 2000s is still valid and was used in this analysis. Where more recent and refined estimates had been made these were substituted. Estimates of the private and social profitability of alternative land uses were updated using recent price information and the results expressed in 2007 equivalent US$. The greatest new challenges, therefore, were in the analysis of land use and land use change and in the aggregate analysis of opportunity costs.

Land use change is based on the mega land uses identified in the previous phases of ASB research and derived from sequential analysis of satellite imagery with appropriate algorithms and sufficient groundtruthing. Each spatial representation ('pixel') of land is characterized in terms of mega land uses at 2 or 3 dates from 1990 to present, with land use change calculated for each pixel for each pair of dates. Aggregation of the information on land use change for all pixels generates a land-use transition matrix for the whole landscape.

For each pixel that experienced a change in time-averaged carbon stock, a calculation was done to generate an estimate of the economic value per unit emission (tonne of CO_2eq). First, the change in net present value was calculated, with positive numbers representing increases in net present value. Second, the units of carbon were translated into units of CO_2. Third, the change in the number of units of time-averaged CO_2eq was calculated, with positive numbers representing emissions of CO_2eq. Finally, the economic value per unit emission of CO_2eq from the pixel was calculated as the change in net present value divided by the reduction in carbon stock measured in terms of units of CO_2eq.

The results of these calculations showed two distinct types of land use change in the sites: *emitting land-use changes* associated with reductions in time-averaged carbon stock and *sequestering land use changes* with increases in time-averaged carbon stock. Separate analyses were done of the opportunity costs of CO_2eq emission from emitting land use change and the benefits and costs of sequestering land use change. Pixels with emitting land-use changes were sorted according to the economic value per unit of CO_2eq emission, starting from emissions generating the greatest negative economic value per unit emission to emissions generating the greatest positive economic value per unit emission. A curve was then constructed to show the cumulative emissions that are associated with different levels of economic value per unit emission. For comparison across sites of different sizes, the horizontal axis is transformed from cumulative CO_2eq emission for the entire area to CO_2eq emission per unit area by dividing the horizontal axis value by the size of the site. Given the concentration of the measures of economic value per unit CO_2eq between 0 and US$10 / hectare, some of the results were expressed in log-10 terms.

The curve that is generated by this analysis can be interpreted as a cost curve for greenhouse gas abatement, or viewed another way, the potential supply curve of greenhouse gas abatement. The curve does not specify who will have to be paid how much to avoid (abate) emissions, but does provide estimates of the average and marginal opportunity costs of emission reduction through avoided deforestation. In practice of course, the abatement of CO_2eq from avoided deforestation would also entail considerable transaction costs (information, contracting and enforcement). These transaction costs would shift the cost curve up.

Pixels with sequestering land-use changes were also sorted according to the economic value per unit CO_2eq emission, starting from the changes that generated the largest negative gains (losses) to the changes that generated the largest positive gains. Again, for comparison with sites of different sizes, the horizontal axis was transformed from cumulative CO_2eq sequestration for the entire area to CO_2eq sequestration per unit area by dividing the horizontal axis value by the size of the site.

Box 3.1 Macroeconomics and mixed farming are key driving forces in Peru

There is growing concern that biofuels and livestock development are amongst the main drivers of deforestation in the Amazon. Evidence from this study suggests that mixed farming (including shifting cultivation mosaics) was the primary driver of forest conversion in the Peruvian Amazon. Very little change was observed for oil palm and pasture lands between 1990 and 2007. Farmers convert high forest or older fallows ranging from 6-20 years of age for agricultural production. Traditional long crop-fallow rotations typically start with upland rice in the first year, followed by two years of maize, plantain or cassava (Fujisaka and White, 1998). Thereafter, farmers often leave fields fallow and, if available, graze cattle. When cattle are available they are mostly incorporated into mixed systems including annual crops-i.e. rice, maize, cassava, plantain or beans. Though cattle are important for livelihoods in the Peruvian Amazon, investments required for pasture and livestock are quite high (livestock at \$300 AU^{-1}, pasture establishment (\$3 ha^{-1}), and fencing, shed and corral at approximately \$100 ha^{-1}). In the ASB farmer survey of 1999, approximately only 23% of farmers had cattle. A majority of farmers with pastures (52%) did not have cattle but almost all of them aspire to get some.

Macroeconomic policy has impacted the development of livestock, hence its direct influence on forest conversion. The Belaunde and the Velazco administrations (60s and 70s) deeded large areas in the Amazon to farmer cooperatives for logging and cattle ranching. These governments also promoted subsidies, price controls and tariff protection. Hence huge logging and livestock associated deforestation in those years. Between 1985 and 1990, the Garcia government responded to economic instability (inflation) by subsidizing credit, fertilizers and chemical inputs and establishing high floor prices for many crops. These policies created incentives for rice and maize production in the Amazon. As a result, farmers increased cultivated areas, hence high deforestation rates for the period 1985-1990. Successive governments have eliminated agricultural credit and price supports, thereby reducing large scale agricultural expansion and associated deforestation. This Andean-Amazon context starkly differs from that of Brazil where government support has been more generous and consistent (Hecht, 1993; Scatena *et al.*, 1996; Vosti and Witcover, 1996).

4. Results

4.1 Land use and land use change

Table 4.1 presents summary information on the land uses that were identified in the 5 study sites.

Ucayali, Peru
Aster satellite images for 1990, 1998 and 2007 were obtained and analyzed. Forest was classified into four types on the basis of canopy cover: more than 95% canopy cover, more than 80% canopy cover, more than 65% canopy cover, and more than 50% canopy cover. The other types of land use that were observed were tree crop systems (one type -- oil palm), crop-fallows types (two types – short-duration fallow, shifting cultivation mosaics), and pasture (a combination of native grasses and *brachiaria*). The change analysis shows a pattern of deforestation that began the 1990-1998 period and escalated in the 1998-2007 period. Large areas of forest became less dense and the area of shifting cultivation mosaics increased. Somewhat surprisingly, the extent of pasture in the whole landscape is still minimal in 2007.

Figure 4.1 presents percentage area coverage for the identified land uses. Figure 4.2 summarizes the percentage changes in coverage per land use type and time period.

Figure 4.1 Percentage area per identified land use for Ucayali, Peru

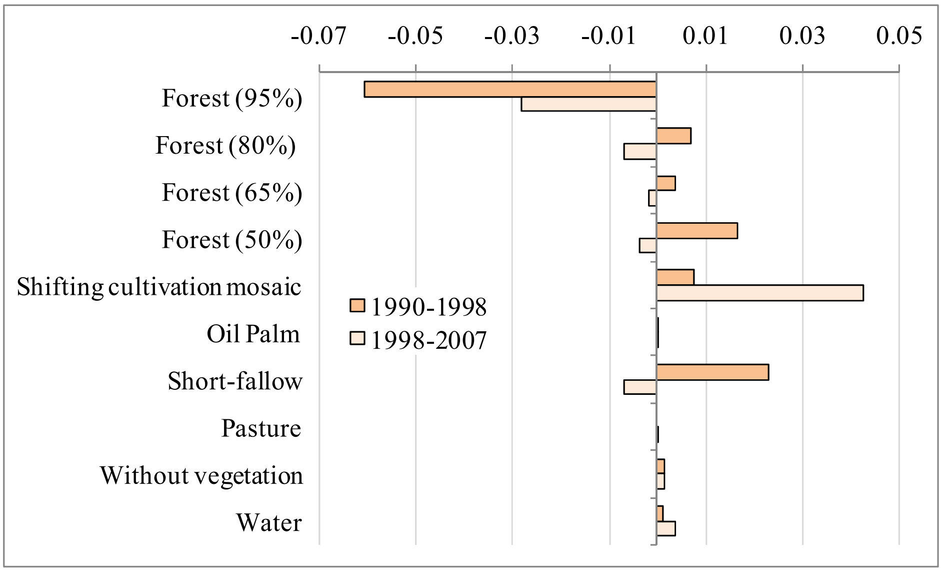
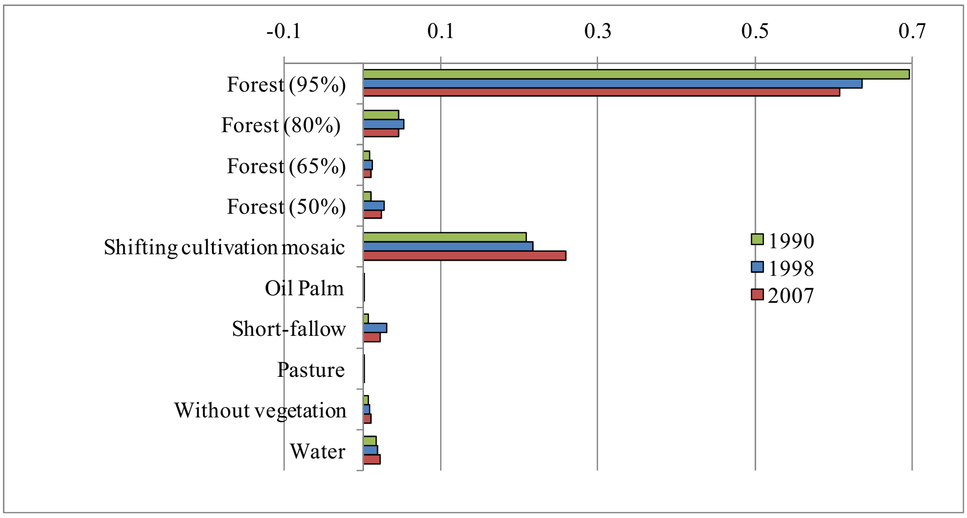


Figure 4.2 Percentage changes in land use for the 1990-1998 and 1998-2007 time periods, Ucayali, Peru.



Cameroon:

The following land uses/land covers were included in the Cameroon analysis:

- High forest—relatively old forest (in both sites, selective logging has occurred in the past but the number of trees harvested per ha is low). Hunting and the gathering of NTFPS from this land use are of some local importance to livelihoods (*Irvingia gabonensis, Coulis edulis, Ricinodendrom heudolotti*)
- Secondary forest—also important for NTFPs as above
- Extensive cocoa—low productivity (265 kg/ha) with limited use of fungicides (Akok only)
- Extensive cocoa with fruit—same cocoa yield as above except fruit surpluses are marketed (Awae only)
- Intensive cocoa with fruit—more intensive use of fungicides and labour results in higher cocoa yield (500 kg/ha) (Awae only)
- Mixed food crop field/short fallow rotation—In addition to the principal crops of groundnuts and cassava, leafy vegetables, plantain, okra, cocoyams and maize are also commonly included and were included in the calculations.
- Melon-seed/plantain/long fallow rotation—melon seed (*Cucumeropsis manni*) is a low yielding high value commodity with a high labour requirement for clearing (long fallows and secondary forest are the norm) and harvesting.

The land use change analysis was developed for Awae and Akok villages from aerial photographs for 1984 and high resolution IKONOS satellite imagery for 2001 (Robiglio, 2007). Because secondary forest was indistinguishable from mature cocoa agroforest and newly established cocoa indistinguishable from the mixed food crop field/short fallow systems it was not possible to estimate the area in cocoa from the image processing exercise. Instead, we combined results from a GPS land use mapping, conducted by ASB in 2001/2002, to get an estimate of the proportion of each land use category that was actually cocoa. This proportion was assumed unchanged from 1984 to 2001.

Table 4.1 ASB meta land use systems and representative systems at the study sites

	Indonesia			Peru	Cameroon
ASB meta land use	**Jambi**	**Lampung**	**East Kalimantan**	**Ucayali, Peru**	**ASB benchmark site**
Forest	Undisturbed forest Logged over forest-high density Logged over forest-low density Undisturbed mangrove Logged over mangrove Undisturbed swamp forest Natural regrowth-shrub	Undisturbed forest Logged over forest-high density Logged over forest-low density Undisturbed mangrove Logged over mangrove Undisturbed swamp forest Logged over swamp forest Natural regrowth-shrub	Undisturbed forest Logged over forest-high density Logged over forest-low density Undisturbed mangrove Logged over mangrove Undisturbed swamp forest Logged over swamp forest Natural regrowth-shrub	Residual forest: Previously logged with some selective logging continuing and NTFP extraction. Tree canopies of 95, 80, 65, 50%.	High forest—relatively intact with some selective logging in the past. Some hunting and the gathering of NTFPs. Secondary forest—also important for collection of NTFPs.
Tree-crop systems	Home garden Coconut Rubber agroforest Cinnamon agroforest Coffee agroforest Rubber Oil palm Tea plantation	Home garden Coconut Rubber agroforest Cinnamon agroforest Coffee agroforest Rubber Oil palm Damar agroforest Fruit-based agroforest Coffee	Agroforest Rubber agroforest Cinnamon agroforest Coffee agroforest Rubber Small scale oil palm Large scale oil palm Plantation	Oil palm	Extensive cocoa—low productivity with limited use of fungicides (Akok only). Extensive cocoa with /fruit—same as above except fruit surpluses are marketed (Awae only). Intensive cocoa with fruit—more intensive use of fungicides and labour results in higher yield (500 kg/ha) (Awae only).
Crop/fallow systems	Agriculture Rice field	Agriculture Rice field Sugarcane	Agriculture Rice field	Shifting cultivation mosaic --combination of forest patches, pasture and annual crops Short fallow -- secondary forest converted to 3 years of annual crops (rice, maize, cassava, plantain, beans) followed by 2 to 6 years of fallow	Mixed food crop /short fallow rotation - groundnuts, cassava, plantain, okra, cocoyams, maize, leafy vegetables Long fallow rotation -- melonseed / plantain / long fallow rotation.
Other	Settlement Grass Open peat Cleared land	Settlement Grass Open peat Cleared land	Settlement Grass Open peat Cleared land	Native grasses or *Brachiaria*	

The results presented in Tables 4.2 and 4.3 show very different patterns of land use change in the two villages. Akok experienced a reduction in high forest (from 26 to 18% of the land area) that was more than offset by an increase in secondary forest (57 to 67%). Areas in other land uses stayed relatively constant. On the other hand, Awae experienced a reduction in high forest (14 to 7%), stable secondary forest, stable cocoa agroforests, and an increase in short-duration fallow (22 to 34%).

Table 4.2: Land use transitions between 1984 and 2001/2 in Akok village, Cameroon

From/To		High forest 2001	Second forest 2001	Ext cocoa 2001	Mixed / short fallow 2001	Mixed / long fallow 2001
		0.18	0.67	0.02	0.08	0.05
High forest 1984	0.26	0.18	0.07	0.00	0.00	0.00
Sec forest 1984	0.57	0.00	0.57	0.00	0.00	0.00
Ext cocoa 1984	0.02	0.00	0.00	0.02	0.00	0.00
Mixed / short fallow 1984	0.09	0.00	0.01	0.00	0.08	0.00
Mixed / long fallow 1984	0.07	0.00	0.01	0.00	0.00	0.05

Source: Derived from Robiglio (2007).

Table 4.3: Land use transitions between 1984 and 2001/2 in Awae village, Cameroon

From/To		High forest 2001	Second forest 2001	Ext cocoa w/fruit 2001	Int coca w/fruit 2001	Mixed / short fallow 2001	Mixed / long fallow 2001
		0.07	0.41	0.05	0.04	0.34	0.09
High forest 1984	0.14	0.07	0.00	0.00	0.00	0.07	0.00
Sec forest 1984	0.42	0.00	0.40	0.00	0.01	0.01	0.00
Ext cocoa w/fruit 1984	0.07	0.00	0.00	0.05	0.00	0.02	0.00
Int cocoa w/fruit 1984	0.02	0.00	0.00	0.00	0.02	0.00	0.00
Mixed / short fallow 1984	0.22	0.00	0.01	0.00	0.00	0.20	0.00
Mixed / long fallow 1984	0.13	0.00	0.00	0.00	0.00	0.04	0.09

Source: Derived from Robiglio (2007).

Indonesia:
Time series of land cover change were analyzed for three provinces of Indonesia (Jambi, Lampung, East Kalimantan) (Figures 4.3, 4.4 and 4.5) that jointly cover 16.2% of Indonesia, ranging in forest cover (using the forest definition chosen by Indonesia for the UNFCCC purposes) from 14% to 85% in 1990 and from 8% to 79% in 2005, while the average for Indonesia was 55% and 36%, respectively. A larger number of land use types were identified in the analysis of land use change. The greater number of land uses was in Lampung (25), followed by Jambi (22) and East Kalimantan (20). A large number of forest (8) and tree-crop systems (10) were identified. Perhaps most interesting for this study, areas of open peat and swamp forests were identified in all three provinces (see Table 4.3). Land cover types were based on a hierarchical legend derived from a large number of groundtruthing points. A total of 2164, 1267 and 712 groundtruthing points have been visited in East Kalimantan, Jambi and Lampung, respectively, over the last 10 years by the ASB partner organizations working in Indonesia. Four spatial strata were used, distinguishing peat from mineral soils (due to their differences in belowground carbon stocks) and areas of high and low accessibility (within 6.5 km of main road or navigable river) because of the affect of accessibility on the profitability of different land use systems. The land use transitions can be further classified as legal and illegal by reference to the existing spatial zoning systems. This allowed us to distinguish between legal and illegal land use change.

Figure 4.3: Summary of land use change in Jambi Province, Indonesia for 1990, 2000 and 2005

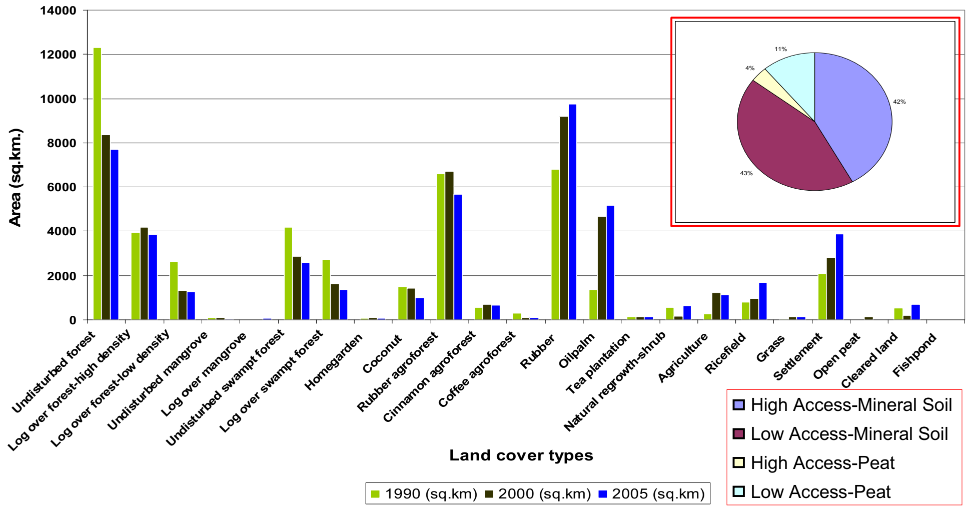


Figure 4.4: Summary of land use change in Lampung Province, Indonesia for 1990, 2000 and 2005

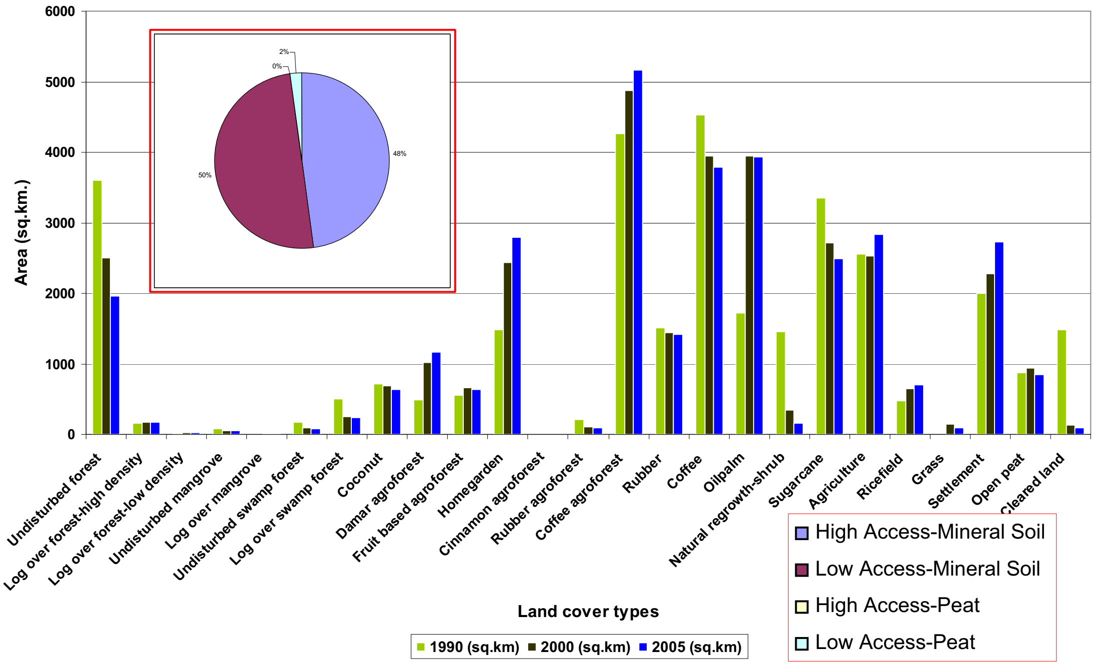
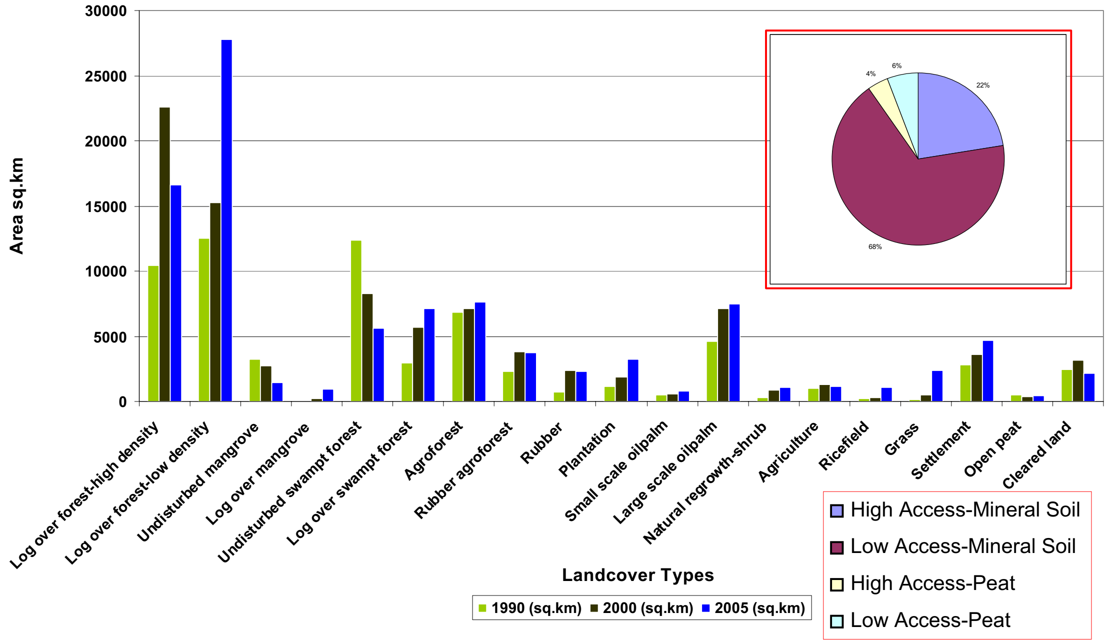


Figure 4.5: Summary of land use change in East Kalimantan Province, Indonesia for 1990, 2000 and 2005



4.2 Time-averaged carbon stocks

Scientists from a number of the ASB partners in Peru worked together in the assessment of above- and below-ground carbon stocks in the various land use systems at Ucayali, following the guidelines discussed in section 2 above. The results are published in Alegre et al. (2000) and reproduced here as Table 4.4. When forest is converted to agricultural uses, above-ground carbon stocks are considerably reduced. Less dense and lower vegetation replaces woody species. As expected, managed forest and older natural fallows have the highest carbon contents. Among the tree-based systems, the time-averaged carbon content of perennial systems is relatively high, ranging from 41 tonnes per hectare for oil palm plantations to 74 tonnes per hectare for rubber plantations (Ucayali). The amount of carbon stored in annual cropping systems is very low (3 to 17 t ha^{-1}). Pastures contained the lowest quantities of carbon (2 t ha^{-1}) (Fujisaka *et al.* 1998; Alegre *et al.* 2000).

Table 4.4. Above ground time-averaged carbon stocks of different land use systems in Yurimaguas and Ucayali, Peru.

Land Use	Above Ground Carbon (t ha^{-1})[a]
Primary	162 [a]
Residual (logged)	123 [a]
Rubber (30 year) w/ kudzu	74
Oil Palm with grasses	41
15-year fallow	126
3-year fallow	21
Maize	8
Cassava	3
Plantains	16
Degraded pasture	5
Degraded	5

[a] includes standing, dead and fallen logs.
[b] *Bactris, Cedrelinga, Inga, Colubrina,* coffee with cover crop of *Centrosema*.
(Source: Alegre *et al*. 2000).

The ASB team originally working in Cameroon estimated the time-averaged carbon stock of cocoa agroforests at 62 tonnes per hectare over a 25 year production period. Here we revise that estimate upward on the basis of the study by Sonwa (2004). Over 60 sites in southern Cameroon, Sonwa (2004) average carbon stocks of 250 tonnes per hectare. He also found the median age of cocoa farms in the region to be over 40 years and the majority of cocoa farms were planted under thinned forest and not after a deforestation episode of slash and burn. On the basis of these assumptions, we arrive at a value of 180 tonnes per hectare for cocoa production systems. The other ASB estimates of carbon stocks were maintained in this analysis.

Table 4.5. Above ground time-averaged carbon stocks of different land use systems in the ASB benchmark site in Cameroon

Land Use	Above Ground Carbon (t ha^{-1})[a]
High forest	250
Sec forest	200
Ext cocoa	141
Ext cocoa w/fruit	141
Int cocoa w/fruit	141
Mixed / short fallow	4.5
Mixed / long fallow	63.3

Table 4.6 presents the time-averaged carbon stock estimates for mineral soils in Indonesia. The same time-averaged carbon stocks were assumed to hold for all three provinces.

Table 4.6 Above ground time-averaged carbon stocks of different land use systems in Indonesia

	Land use type	Time-averaged carbon stock per hectare (tonnes / ha)
1	Undisturbed forest	300.0
2	Log over forest-high density	250.0
3	Log over forest-low density	150.0
4	Undisturbed mangrove	200.0
5	Log over mangrove	100.0
6	Undisturbed swamp forest	200.0
7	Log over swamp forest	200.0
8	Homegarden	21.8
9	Coconut	90.7
10	Damar agroforest	114.8
11	Fruit-based agroforest	116.1
12	Rubber agroforest	62.1
13	Cinnamon agroforest	60.00
14	Coffee agroforest	17.2
15	Rubber	46.8
16	Oilpalm	31.0
17	Tea plantation	7.5
18	Natural regrowth-shrub	26.8
19	Sugarcane	12.5
20	Agriculture	11.9
21	Ricefield	1.0
22	Grass	2.0
23	Settlement	4.1
24	Open peat	4.1
25	Cleared land	3.9

5. Opportunity costs of CO_2 emissions from land use change

Section 3 above describes how the information on time-averaged carbon stocks, potential profitability and land use change is processed into disaggregated measures of the opportunity cost of CO2 emissions from land use change in the 5 sites. It is likely that the land use changes in the site will generate all four possible combinations of time-averaged carbon stock and net present value. Some of these changes represent clear tradeoffs: increases in NPV with decreases in carbon or increases in carbon with decreases in NPV. Others represent win-win outcomes of increased NPV and carbon, while others represent lose-lose outcomes of decreased NPV and decreased carbon.

The NPV – carbon tradeoff results are cumulated for all landscape units (pixels) that changed use, starting with units that had the highest negative opportunity costs (pixels that had the highest ratio of increase in NPV per unit increase in time-averaged carbon stock CO2-eq) and moving to units with greater and greater opportunity costs.

5.1 Peru

Figure 5.1 presents the abatement cost curve for the Ucayali site in Peru for the period 1990 to 1998, while figure 5.2 presents the same curve for the period 1998 to 2005. In both cases, the blue line assumes a 10% private discount rate and the red line assumes a 3% social discount. The results show that in both periods the majority of the land use changes generated less than $5 / tonne CO_2-eq lost. Results were somewhat higher in the 1990 to 1998 period than in the 1998 to 2007 period. Low productivity and prices for forest and agricultural goods contribute to a low opportunity cost for carbon. From this information it appears that Ucayali would be suitable for establishing a cost-effective REDD program.

Figure 5.1 Abatement cost curve with 3% and 10% discount rate, Ucayali 1990-1998

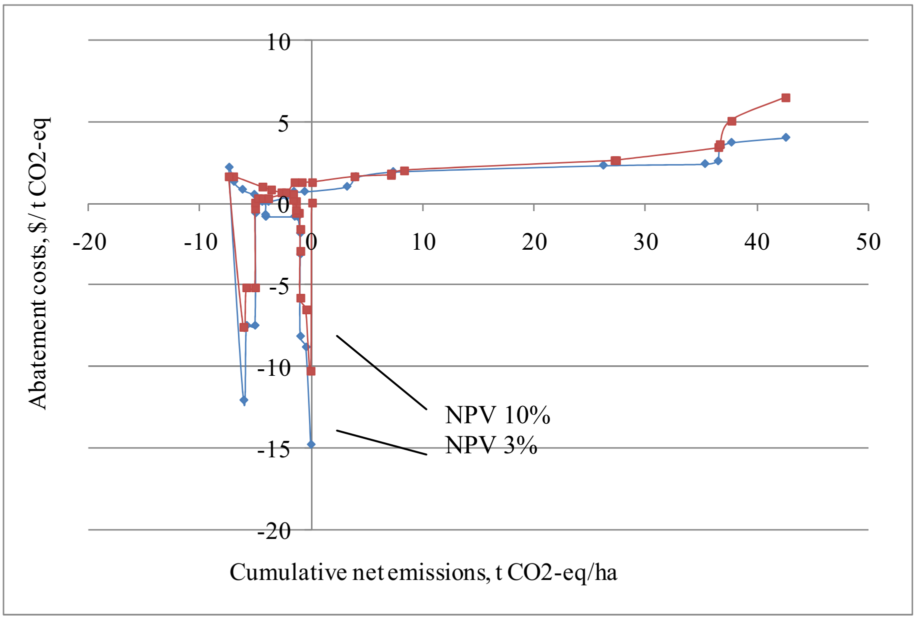
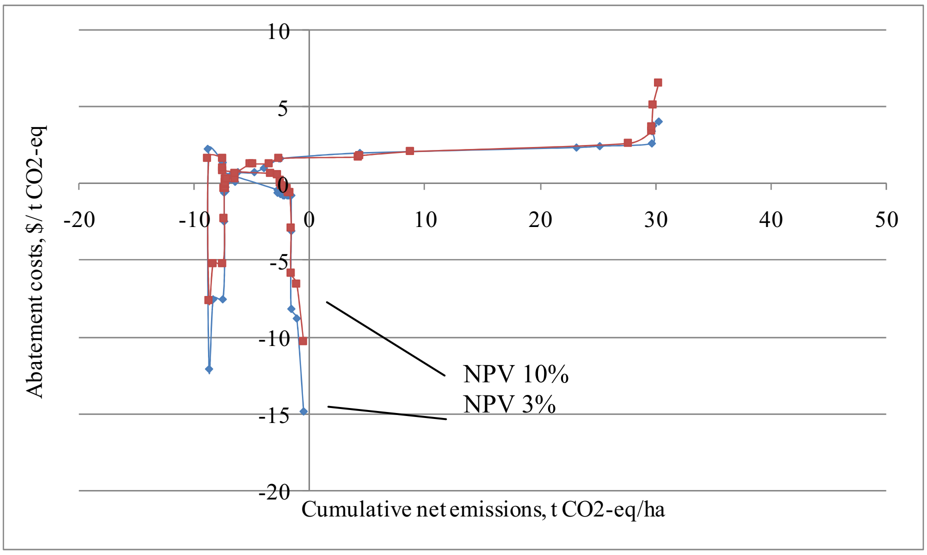


Figure 5.2 Abatement cost curve with 3% and 10% discount rate, Ucayali 1998-2007



5.2 Cameroon

Table 5.1presents the changes in land use for the two sites along with changes in carbon stocks and the private NPV using a discount factor of 0.15 at the landscape levels. The most surprising finding is that the total carbon stock in Akok appears to have remained unchanged, actually increasing albeit only slightly (0.004%). This is mainly due to the increase in secondary forest and cocoa, and the decrease in low C food cropping systems which offset a decline in high forest. At the same time that carbon was increasing, the total private NPV decreased by over 11 percent at the landscape level. The estimated increase in area devoted to cocoa was 37 ha which represents a 20% plus increase over 1984 cocoa tree stocks. The other two agricultural land uses, both largely subsistence-oriented land use systems, decreased in area.

The situation in Awae is diametrically opposed to that of Akok. The total carbon stock is estimated to have declined by about 15 percent over the 18 years considered. The bulk of the decline is attributable the nearly 50% decrease in the area covered by high forest and the significant increase in low carbon food crop systems. The private NPV in 2001 is 21 % greater than in 1984, mainly because of the increase in the mixed food crop system which grew at a rate of over 3 percent per annum. The total area planted to cocoa was virtually unchanged over the period of analysis.

Table 5.1 Estimated change in land use, carbon stocks and net present value (social discount rate = 15%) by type of land use and for overall landscape in Cameroon sites.

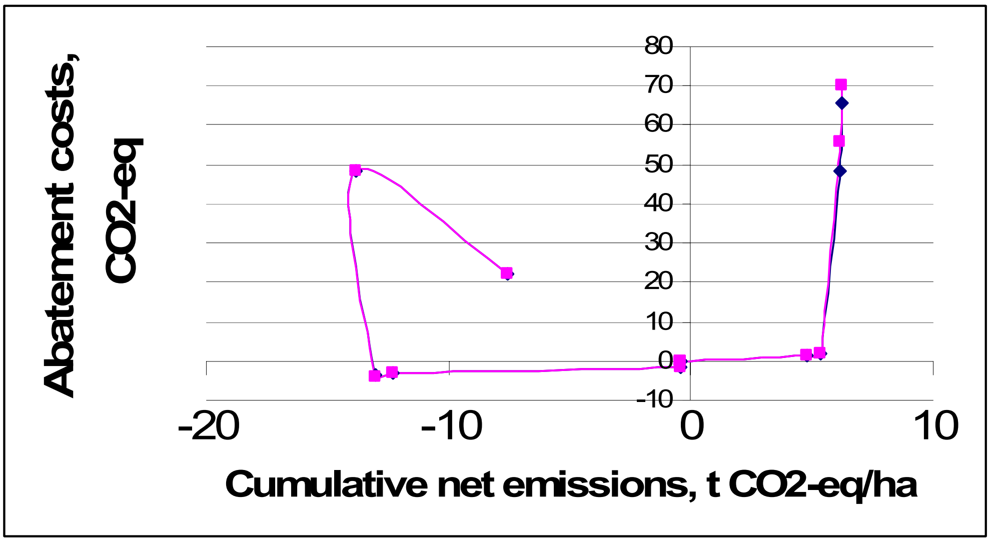
	Akok					Awae				
	Land use in 1984 (proport. of total)	Land use in 2001 (proport. of total)	Net land use change	Net change in carbon stock	Net change in NPV	Land use in 1984 (proport. of total)	Land use in 2001 (proport. of total)	Net land use change	net change in carbon stock	Net change in NPV
high forest	0.2573	0.1836	-0.0737	(211,977)	(56,449)	0.1422	0.0736	-0.0687	(18,279)	(4,868)
secondary forest	0.5739	0.6682	0.0944	217,228	28,630	0.4247	0.4147	-0.0100	(2,135)	(281)
extensive cocoa	0.0153	0.0186	0.0033	6,766	60,010				-	-
extensive cocoa w/fruit	0.0000	0.0000	0.0000	-	-	0.0679	0.0529	-0.0150	(2,885)	(47,021)
intensive cocoa w/fruit	0.0000	0.0000	0.0000	-	-	0.0226	0.0353	0.0126	2,418	78,785
mixed food crop field/short fallow rotation	0.0857	0.0754	-0.0103	(539)	(213,375)	0.2157	0.3358	0.1201	579	203,270
melon-seed/plantain/long fallow rotation	0.0678	0.0541	-0.0136	(9,926)	(213,495)	0.1267	0.0878	-0.0390	(2,624)	(42,591)
Total for landscape				1,553	(394,679)				(22,926)	187,294
				0.072%	-11.3%				-14.8%	21.3%

Source: Derived from Robiglio (2007).

For Awae, the 23,000 t draw down in carbon stocks generated approximately $243,000 in NPV evaluated at private prices. Thus on average, each ton of carbon emitted generated about $11 in value. If we use a social discount rate of .001 instead of .15, the opportunity cost is increased to $28 per ton. In Akok, the decline in subsistence farming activities and substantial increase in secondary forest led to an 87 t increase in carbon stocks and an 11% decrease in NPV.

The carbon abatement curves for a discount rate of 0.15 % are presented in figure 5.3 below. The curve combining both sites, weighted by area. For the carbon emitting site of Awae, the largest portion of the emissions was generated at an abatement cost of less than $8 in social NPV.

Figure 5.3 Carbon Abatement Curves for Awae and Akok, discount rate =0.001



5.3 Indonesia

Jambi

In Jambi province, carbon emissions are fairly evenly distributed among a number of land use transitions. Without considering emissions from peat, the results indicate carbon emitting land use changes in Jambi have generated economic benefits. Foregoing these land use changes would entail positive opportunity costs. Accessibility plays an important role on determining the level of opportunity cost. For example, conversion of logged-over forest to oil palm is associated with an opportunity cost of less than 5 US$ per CO_2-eq tonne abatement cost in low accessibility areas, but an opportunity cost of more than 5 US$ per CO_2-eq in high accessibility areas. Compared to East Kalimantan, there are fewer limiting factors, people have more livelihood options, and population pressure is moderate. However, as shown in figure 5.4 and table 5.2, the addition of peat changes the figures drastically, with a much greater percentage of the carbon emissions generating returns less than $2.50 per tonne CO_2-eq.

Lampung

In Lampung the main sources of deforestation are logging and conversion of forest to multistrata coffee, which mostly happens in the area surrounding and inside the national park. Between 1990 and 2000, 48% of all forest conversion in Lampung was illegal; between 2000 and 2005 the percentage of conversion that was illegal was 82%.

The price elasticity to NPV of coffee is also quite high compared to that of rubber but not nearly as high as that of oil palm. The economic gain from planting/growing biomass is the highest among three provinces, i.e., 85.6 $/t CO2-eq (Table 3). This creates a potential threat to the forest area for land grabbing, which in Lampung only can be found in the national park. Law enforcement will need to balance the strong economic drivers in this area.

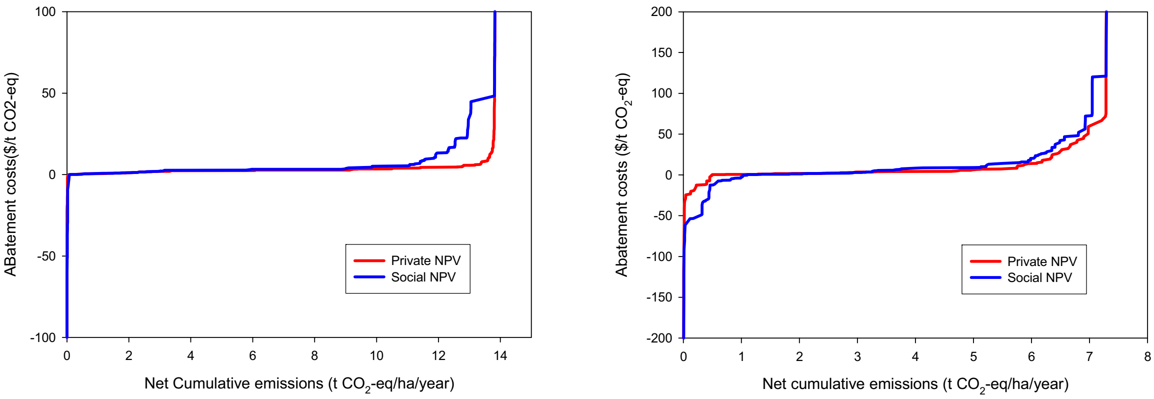
East Kalimantan:
In East Kalimantan it is shown that most AFOLU carbon emissions are produced from logging activities (forest degradation), in which most of the emissions lead to less than 5 $ return per ton CO_2-eq (Table 5.2). Low accessibilities cause high transportation costs, low market access, low population density and lack of economic opportunities which can be seen from Figure 5.4, where most of the land uses that generate low economic returns are found in areas with low accessibility. In the lower end of abatement costs, there are some imperata grassland took over degraded forested area. Palm oil plantations have been established in some areas, but due to conflict with local people, have been poorly managed and abandoned.

The area associated with emitting land use change is extensive and the mean emissions from emitting land use changes high. The area of re-growth and re-planting is comparable to the area of emission. However, the mean sequestration per unit area is quite low, only 4.3 t CO2-eq/ha/y. The mean economic gain from the growing and planting is also low compared to other provinces, i.e., 28.6 $/t CO2-eq (Table 5.2).

Table 5.2 Summary of emission and sequestration in areas and economic gain in the three provinces of Indonesia

	East Kalimantan	Jambi	Jambi (incl. peat)	Lampung
Mean emission from total area (t CO2-eq/ha y)	13.832	7.256	31.234	3.616
Mean sequestration from total area (t CO2-eq/ha/y)	0.349	0.683	0.683	0.564
Net mean emission from total area (t CO2-eq/ha/y)	13.483	6.573	30.551	3.052
Area of emitting luc (ha/y and % from total area)	216,710 (5.99%)	170,783 (18.18%)	170,783 (18.18%)	39,578 (6.27%)
Area of sequestering luc (ha/y and % from total area)	295,368 (8.17%)	10,211 (1.09%)	10,211 (1.09%)	24,542 (3.89%)
Mean emission from emitting luc area only (t CO2-eq /ha/y)	230.918	39.912	171.804	57.671
Mean sequestration from sequestering luc area only (t CO2-eq /ha/y)	4.274	62.661	62.661	14.499
Mean private NPV from sequestering luc ($/t CO2-eq sequestration)	28.634	70.434	69.880	85.763

Figure 5.4 Abatement costs with private and social NPV for East Kalimantan (a), Jambi (b) and Lampung (c) without emissions from and for Jambi (d) with emissions from peat



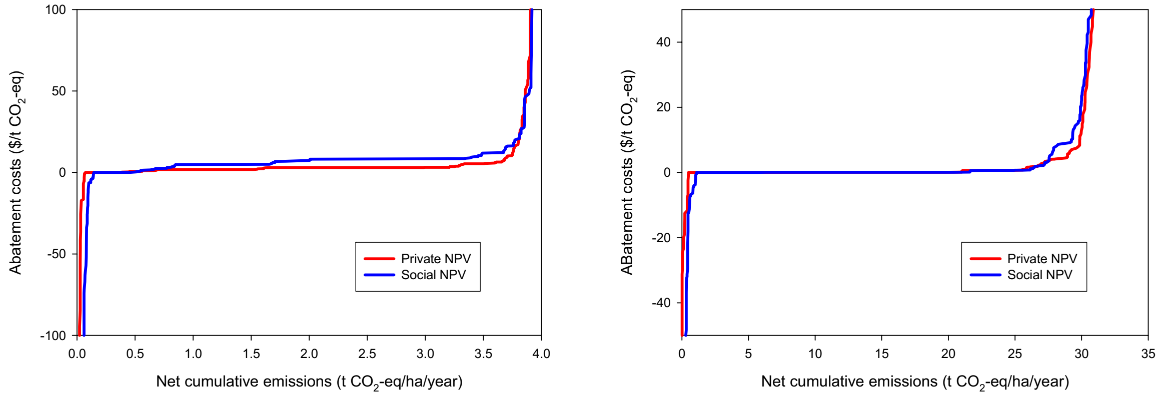
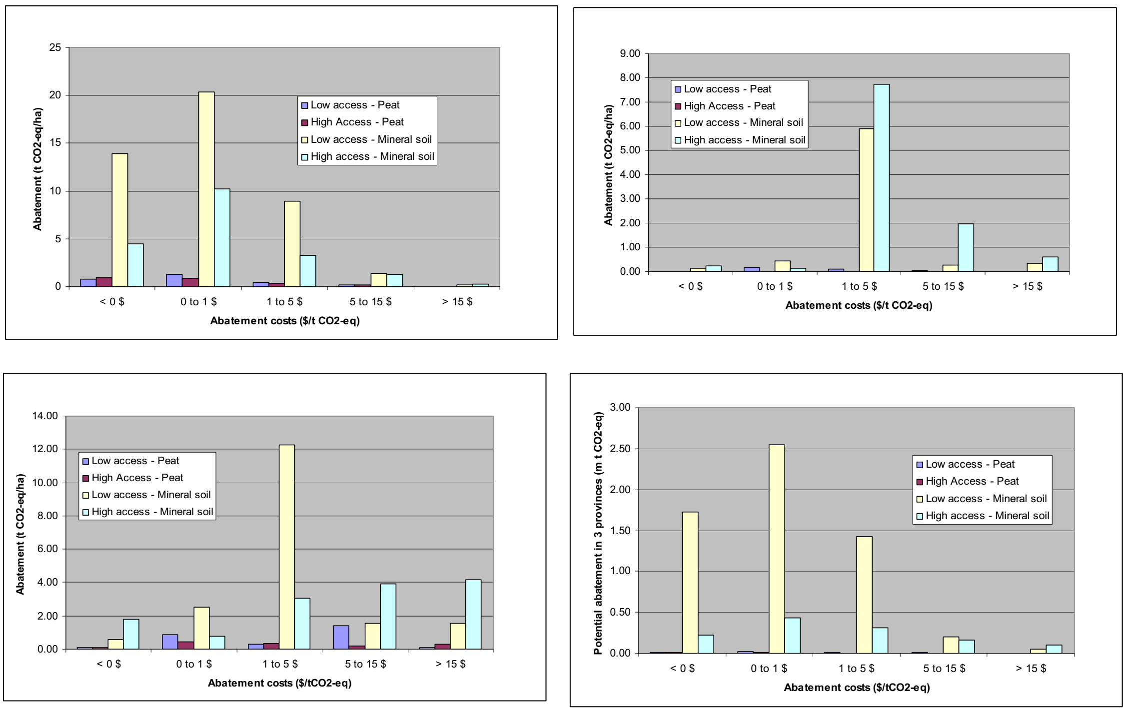


Figure 5.5 displays the abatement cost information differently. It shows the amounts of CO_2-eq that are generated at different levels of CO_2-eq opportunity cost. In other words, it shows the potential supply of CO_2-eq abatement for different CO_2-eq price levels. For ease of cross-site comparison, figures 5.3 and 5.4 express quantities of emissions in terms of CO2-eq per hectare. Multiplying by the number of hectares in the province would generate a measure of the absolute potential supply.

Figure 5.5 Abatement potential per unit area for each level of abatement cost under different zones in East Kalimantan (a), Jambi (b) and Lampung (c), and total potential abatement from 3 provinces (d)

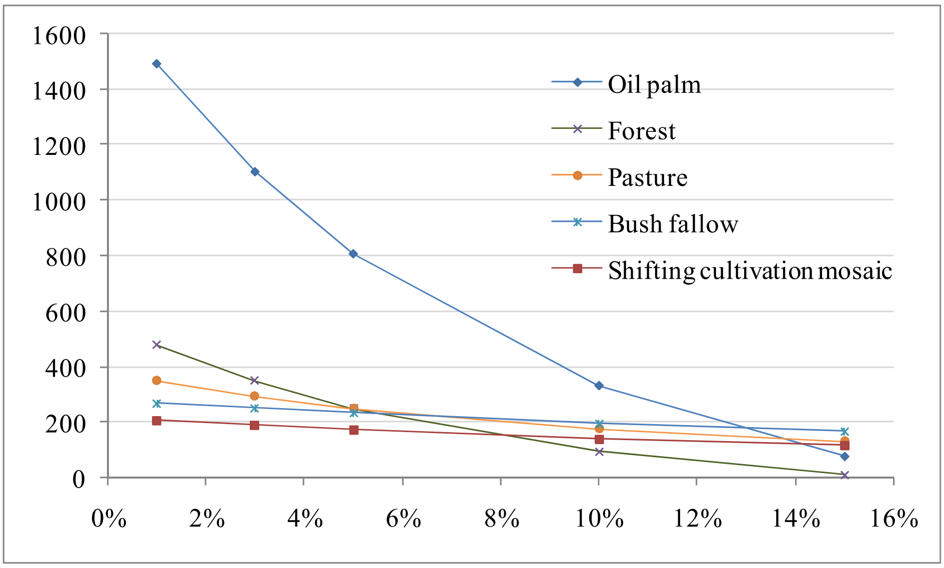


5.4 Social and private discounting of future revenues and costs

This chapter has so far focused on private returns to alternative land uses and the potential for payments for carbon storage to offset the private economic benefits of shifting from high to low carbon land uses. Private returns depend upon farm-level prices for production inputs and outputs, which are often distorted by taxes or subsidies. Private calculations of net present value discount income received in future periods by a factor that accounts for the interest rate in local markets. Calculations of returns to society take account of price distortions and reflect social discount rates.

Figure 5.6 presents results of an analysis of the sensitivity of land use returns to discount rate for the Ucayali site in Peru for the period 1998 to 2007. The results reveal that the five land use systems become of nearly the same value at a 13% discount rate. Longer term projects such as oil palm and harvesting reforestations become less attractive, become of less net present value, as the discount rate increases. In contrast, pastures, bush fallows and shifting cultivation mosaics are not as affected by discount rates.

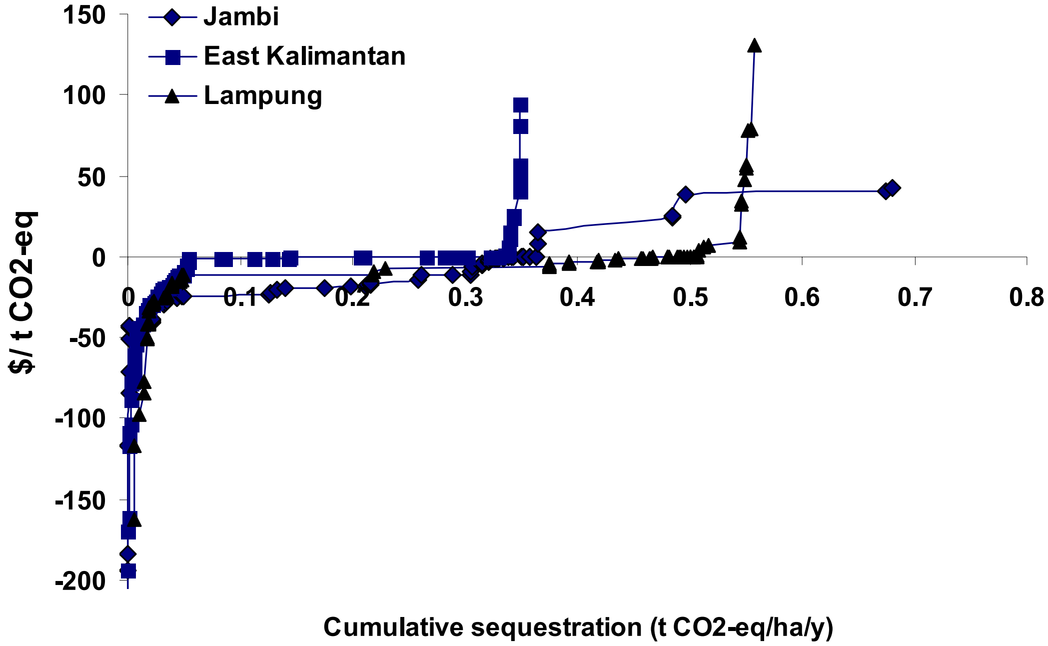
Figure 5.6 NPV profit land use per discount rate (1998-2007)



5.5 Economics of carbon-sequestering land use change in Indonesia

As noted in section 5.3 above, the three provinces of Indonesia included in this analysis have experienced both carbon-sequestering and carbon-emitting land use changes over the last 20 years. While the analysis in this report concentrates of the changes in net present value associated with the carbon losses, further analysis of the data on the carbon sequestering land use changes reveal important differences between the provinces. Figure 5.7 aggregates the pixel-by-pixel data on net present value and carbon stocks for all carbon-sequestering land use changes in the three provinces between 2000 and 2005. Points below the X-axis show amounts of land use change that generated both increases in carbon and increase in net present value. The results show minimal increases in private profitability from sequestering land use changes in East Kalimantan, where most sequestering land use changes were regrowth of previously logged forests. Returns were much higher in Lampung, where large increases in profitability and time-averaged carbon stocks were associated with the switch from simple coffee to multistrata damar agroforestry systems, and in Jambi, where similar increases were associated with from land use changes from croplands to rubber systems.

Figure 5.7 Aggregated pixel-by-pixel data on net present value and carbon stocks for all carbon-sequestering land use changes in the three Indonesian provinces between 2000 and 2005.



6. Conclusions and Discussion

The ASB partnership has previously illustrated some of the tradeoffs associated with alternative land uses practiced in the tropical forest margins. The tradeoff analysis shows that there are few easy wins. The intact forests that generate the highest amounts of time-averaged carbon tend to generate low amounts of annual income. Vice versa, some of the land uses that generate the highest amounts of income have very low levels of carbon. The tradeoff analyses also suggest that there are some achievable win-win solutions, where carbon-sequestering land use changes also increase income.

This paper has built upon the comparative static analysis of tradeoffs to produce a landscape-level understanding of land use transitions and the implications of those transitions for overall carbon stocks and future revenue streams. The returns show that most land-use transitions – both emitting land use changes and sequestering land use changes -- reflect underlying economic incentives. Market conditions, property rights, interest rates and production relationships all have a role in defining incentives. At present there is little incentive for farmers or governments to maintain forests for the carbon value of the standing forests. This paper helps address the question: could emitting land use changes been reduced if farmers' had considered carbon values in their economic decision making?

The answer is a qualified yes. Over the last twenty years the five sites considered in this study have emitted huge amounts of carbon. While some of those land use changes have resulted in large increases in net present value, the majority of that carbon loss has generated modest economic gains and often led to unsustainable land use practices. If appropriate financial incentives had been targeted to reward farmers for the carbon value of their forest resources, it is highly likely that a large amount of deforestation and CO_2 emission would have been prevented. Three land-use change transitions stand out for special attention: (1) logging and subsequent conversion to extensive production of annual crops in sparsely-populated areas of Indonesia (East Kalimantan), Peru (Ucayali) and Cameroon (Awae); (2) conversion of forests to simple coffee systems in Lampung; and (3) all conversion of peat forests in Jambi province.

Economic rewards for carbon storage and carbon sequestration could also be effective in increasing land use transitions from lower to higher carbon land uses. Land use transitions of this type occurred in almost all sites included in this study. However, not all sequestering land use changes had significant effect on carbon stores at the landscape scale. The main sequestering land use changes in East Kalimantan, for example, involved the slow recovery of degraded forests and modest improvements in carbon stores. Land use transitions that converted agricultural lands into multi-strata agroforestry systems in Lampung and Jambi Provinces, on the other hand, generated large increases in time-averaged carbon stocks.

The results suggest a number of significant technical challenges for the design of REDD mechanisms. First, the mechanisms must provide rewards that will consistent with overall carbon management at the landscape and national scales. Forestry agencies should consider forest resources across the landscape, and not be bound by arbitrary definitions of what is or what is not a forest. They should also not be given incentive to strong guard a few intact forest blocks to the neglect of forest resources elsewhere in the landscape. Secondly, there is a need to target carbon conservation incentives to areas at greater risk of future deforestation. Some programs in Latin America actually target conservation payments to risk areas identified through econometric studies. There might be benefits from targeting carbon conservation incentives through a combination of quantitative analysis of the risk of carbon loss through land use change and reverse auction approaches that encourage farmers to self-select into carbon conservation contracts. There may be instances – perhaps the peat forests and peat lands of Indonesia – that justify a compensated shift of ownership from private to public hands.

Overall, the goal of programs of carbon conservation incentives should be promote forest transition pathways that maintain more intact forests, promote more rapid afforestation, and sustain the livelihoods of smallholder farmers living in proximity to forests. Alternative pathways of land use transition must also be alternative pathways of development and alternative profiles of public finance and investment.

Avoided deforestation can be associated with alternative development, but not sustained under-development.

This study helps to undermine the strong economic motivations for deforestation. Results for Peru clearly show that the more that people discount the future, the greater the incentive to deforest and the lower the incentive to invest in reforestation. This holds true at both the private and public levels. Farmers with poor access to credit and insurance and low security of property rights will tend to have higher discount rates; governments concerned about short-term election prospects will also tend to disregard long-term projects like forest protection and sustainable forest management. Given the market incentives for extraction of timber resources, there will always in a need for enforcement of forest boundaries as part of landscape solutions. Situations such as found in Lampung, where most deforestation occurs illegally within and around the national park, undermine the credibility of plans for implementation of REDD.

There also are considerable institutional challenges for carbon conservation incentive mechanisms. We note just a few of these challenges that are highlighted by the results of this study. First, we note that there is a close relationship between market access and opportunity costs of carbon: poor market access translates into low opportunity costs of CO_2 emissions from deforestation. But poor market access is likely to be associated with weak institutional development and high costs for administering and monitoring carbon conservation contracts. Further, poor market access is likely to prompt farmers to focus on minimizing risk and subsistence food production, likely making them less responsive to market incentives for carbon conservation. Thus until market institutions evolve, the largest portion of the decline in carbon stocks in southern Cameroon and most of the Congo basin where the problem is the same will be beyond the scope of REDD mechanisms.

The study highlights research achievements and limitations. A major achievement of the research is the simple geographic coupling of time-averaged carbon stocks and net present values as overall indicators of complex, non-linear patterns, which allow for direct attribution of shifts in carbon stocks and economic value, the constructive of opportunity / abatement cost curves, and ultimately the spatial targeting of carbon conservation incentives. On the other hand, the technical results from Cameroon show constraints on the use of remote sensing to identify land use types. The remote sensing analysis done in Cameroon was not able to distinguish cocoa agroforests from secondary forest or to distinguish between field crops with widely varying economic returns.

In the context of Indonesia, our study team has identified 2 key concerns that shape discussions of any international instrument or mechanism for REDD. One concern is that reduced emissions from deforestation will hamper economic development for very poor people. The results suggest that this ‘poverty’ (or need for economic growth) argument applies to only a fraction of emissions. Most emissions are associated with very low returns per tonne of CO2-eq emitted. A second concern is that poor people will lose legitimate rights to develop farms and business on forest lands. This argument is weak in the case of Indonesia where we have found that the majority of emissions are in breach of existing national laws. The third concern is that reduced deforestation at a national scale in countries such as Cameroon, Peru and Indonesia will require investments that the countries cannot bear on their own, and that they should not be expected to bear. Openness to co-investment will have to be the major share of foreign payments to Indonesia for reducing its pollution of the atmosphere, linked with a real commitment by Indonesia to bring emissions under control.

For all those concerned about the rate of climate change, the data indicate that a large share of the emissions can potentially be avoided by a modest co-investment by international stakeholders, offsetting the small economic gains that are currently made by forest conversion. On the other hand, a concern of ‘flooding the market’ for carbon credits has contributed previously to not including these emissions in the global rules, because they are less costly than investment in clean energy. As a political platform now exists for considerably stronger emission reductions, the carbon markets will be able to provide for these ‘easy’ emission reductions, while still providing funds for investment in cleaning up the industry and energy sectors as currently done under the Clean Development Mechanism.

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ASB

PARTNERSHIP FOR THE TROPICAL FOREST MARGINS

United Nations Avenue, Gigiri, PO Box 30677, Nairobi, 00100 Kenya
Phone + (254) 20 722 4000, Fax + (254) 20 722 4001,
Via USA phone (1-650) 833-6645, Fax (1-650) 833-6646
Email: asb@cgiar.org, Website:www.asb.cgiar.org

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